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Manufacture of Non-Ferrous Seamless Tubes by Piercing and Extrusion Methods

By Gilbert Evans

The practical phases of rotary piercing and of extrusion methods for tube manufacture are reviewed. For the modern tube works it is claimed that both the rotary piercer and the extruding press are essential.

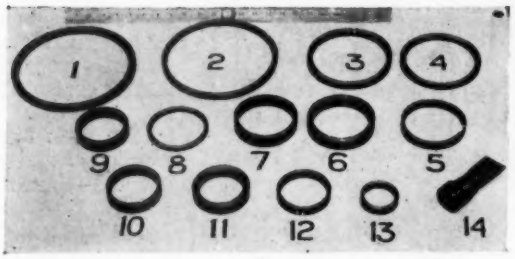


Fig. 1.—A range of products which represents the normal practice of a modern rotary mill.

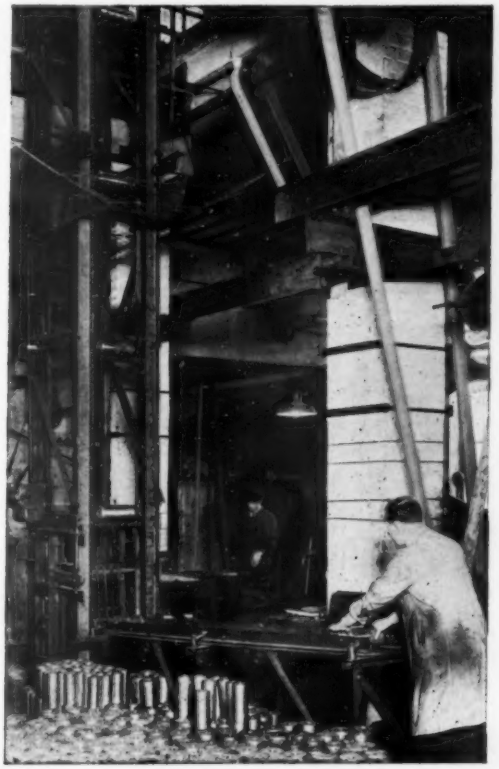


Fig. 2.—Automatic conveyer delivering solid ingots to the charging door.

IT is necessary to reiterate the opinion[1] that in modern manufacture of seamless tubes it is essential to employ both the rotary piercer and the extrusion press, the first-named for production of tubes of large and the latter for tubes of smaller diameters. By means of the rotary machine, equipped with the necessary power and adjustments, shells capable of being cold-drawn to 20 in. are being regularly produced, and there is no reason why 24 in. diameter or more should not be attained. As stated previously, this is accomplished by first piercing the solid billet and supplementing this process by a series of expanding and re-expanding passes through the same mill until the necessary diameter and wall thickness are attained. Applied to ordinary commercial and running sizes of from 7 in. down to 2 in., the desired diameters are produced from the solid billet in one operation, direct from the solid round billet, to the weight of which there is practically no reasonable limit. The standard length of the casting varies from 4 ft. to 6 ft., but diameters of 9 in. and 12 in. of 7 ft. in length are at times necessary to produce large sizes by the supplementary expanding. Reference to the Fig. 1, will indicate the everyday products of a modern rotary mill, the sizes of which are given in the accompanying table.

The vertical hydraulic extrusion press is particularly well adapted for the production of shells for finishing, with a minimum of cold-drawn treatment, into small-diameter tubes, although the author is aware that diameters up to 7 in., with comparatively thin walls, are also being regularly manufactured. Intensive attention to the smallest details is necessary to avoid eccentricity in thickness, which is clearly the greatest bugbear to the practical tube manufacturer.

TABLE.

Dimensions of Sample.			Original Billet Size.	Remarks.
No.	O. D.	Wall.		
	In.	In.	In.	
1	$8\frac{3}{4}$	$\frac{1}{2}$	6	Expanded
2	$8\frac{1}{4}$	$\frac{11}{32}$	5	Expanded
3	$5\frac{15}{16}$	$\frac{3}{8}$	4	Expanded
4	$5\frac{13}{32}$	$\frac{13}{32}$	$3\frac{1}{2}$	Expanded
5	$4\frac{7}{32}$	$\frac{7}{32}$	4	Pierced Only
6	$4\frac{13}{32}$	$\frac{11}{32}$	4	Perced Only
7	$4\frac{3}{16}$	$\frac{7}{32}$	$3\frac{3}{4}$	Pierced Only
8	$4\frac{1}{32}$	$\frac{9}{32}$	$3\frac{1}{2}$	Pierced Only
9	$3\frac{7}{16}$	$\frac{1}{16}$	3	Pierced Only
10	$3\frac{1}{2}$	$\frac{9}{32}$	3	Pierced Only
11	$3\frac{13}{32}$	$\frac{3}{8}$	$2\frac{1}{2}$	Pierced Only
12	$3\frac{3}{8}$	$\frac{7}{32}$	$2\frac{1}{2}$	Pierced Only
13	$2\frac{3}{8}$	$\frac{13}{64}$	2	Pierced Only
14	$1\frac{25}{32}$	$\frac{5}{32}$	$1\frac{1}{2}$	Pierced Only

The Serck Extrusion Patents.

This press, manufactured in Great Britain under Serck's patents by Messrs. Fielding and Platt, Ltd., Gloucester, is of simple design, and reliable for the uniformity of its

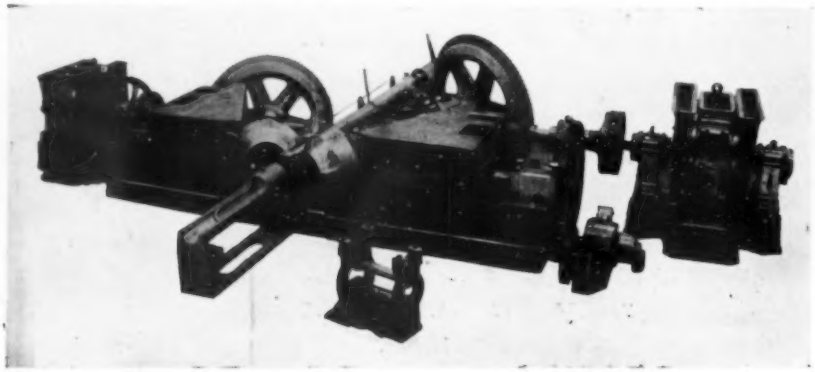
1 Gilbert Evans, "Rotary Piercing and Extrusion for Tube Manufacture," METALLURGIA, No. 8, pp. 45-47.

products, and may be erected in keeping with its environment either on floor level with vault below, or on a raised platform, so that the resultant shell is delivered on to the working floor of the department. A curved channel from the delivery end of the plant receives the shell, and while still in a hot state the product is straightened by suitable methods, entirely free from kinks or waves, a state which is essential to the subsequent finishing treatment by the cold-drawing process. The furnace for heating of billets by gas, electricity, or oil fuel is arranged in suitable proximity to the press, and, in the case of the raised platform, the solid billets are delivered to the charging door by means of an automatic conveyer, Fig. 2. The extrusion press under consideration may be operated direct from pumps or from accumulator pressure, and consists chiefly of the main pressure cylinder and ram, sliding container casing and container, with valve-box under the direct control of the operator; an assistant attends to the reheating furnace, conveying the material, inserting it into container and adjusting the guide bush and piercing and extruding mandrel.

The chief operator changes both the die and mandrel after each process, which period allows ideal cooling of these important details, and he also positions the cutting-off tool and removes the thin disc of scrap from the container by means of a hook. The diagrammatic sketch at Fig. 3, although not drawn to scale, illustrates the "principle" of the Serck process. While the diagram is self-explanatory, a brief description is given for reference.

At the start of the shift's work, the container is slightly heated, and the inside surface, after being thoroughly cleansed, is prepared with a dressing suitable for the non-ferrous material. When the billet whose surface has been turned attains the required temperature it is withdrawn from the furnace hearth and inserted in the container. The guide bush is placed in position on the top of the container and billet, and the piercing-extruding mandrel placed in the guide-bush. As will be observed by the diagrammatic sketch at A, the last-named tool is self-centring in the ram attachment, and is floating and not fixed as in some presses. The combination of the floating mandrel and guide-bush is, from personal experience in similar plant in use in the steel tube trade, a great factor in producing concentric shells. Immediately the tools mentioned are in position the leading hand admits the pressure from pumps or accumulator to the main ram, which forces the mandrel through the billet. On completion of this piercing stroke the mandrel enters the extrusion die and continuance of the pressure forces the pierced billet over the mandrel and through the orifice of the die, the difference in the tools' respective diameters governing the thickness of the resultant shell.

Fig. 4.—Evans' rotary piercing machine. Although piercing by hydraulic pressure is still used, the introduction of the rotary piercing machine is being increasingly adopted.



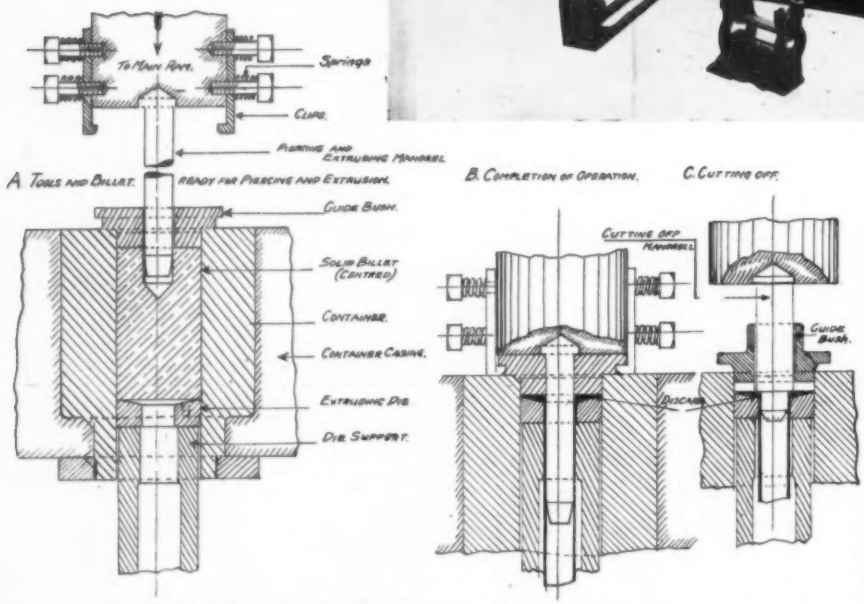


Fig. 3.—Three stages of Serck's patent tube-extruding process.

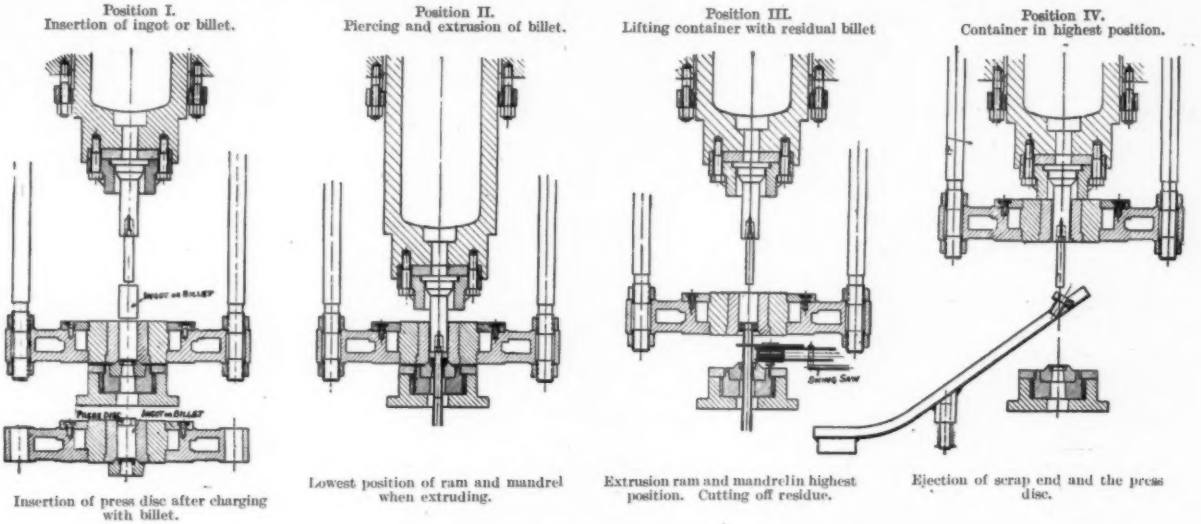
In this patent process the whole of the container and casing progresses through the actual extruding until the guide-bush almost contacts with the bottom extruding die. Hence the term sliding container. For the extraction of the mandrel a novel gadget in the form of two hooked brackets engages the top collar of the guide-bush as at B, and the upward stroke of the main ram—which is governed by two small hydraulic cylinders contained in the body of the main ram—extracts the mandrel from the shell. Meanwhile, the container and casing is held down at its finishing position by an outside catch. A second guide-bush and cutting punch is put in position, and pressure applied to the main ram effectually severs the long shell, leaving a small disc of discard or scrap, which is removed by the operator, who also changes the die. The release of the catch and application of compressed air returns the container to its original position ready for the next operation. The output of the plant under review is governed by the billet-heating capacity of the furnace and power supply, and a shell 20 ft. to 40 ft. long is extruded in about 30 secs. from the time the solid billet leaves the furnace fore-plate.

In the length of the container it is necessary to allow for elongation of the billet while under the piercing operation. These presses are made of 1,000 and 500 tons ultimate pressure, and are of steel throughout, the working surface of the main ram being sheathed by a gun-metal case. Adaptations are made for working pressures up to 3,000 lb. per sq. in., and complete plants are working successfully in Great Britain and on the Continent. Successful trials have been carried out in manufacture of seamless tubes of stainless steel under working conditions, but at a much higher temperature, similar to those governing extrusion of non-ferrous metals.

The Fried. Krupp Vertical Hydraulic Extrusion Press.

In recent times many British and Continental manufacturers of non-ferrous tubes have installed and successfully worked the Fried. Krupp vertical hydraulic extrusion press, and brief reference is necessary to some of the principles included in its design. The main cylinder is embodied in the press frame, which is of cast steel, this method ensuring the necessary rigid connection and eliminating the possibility of any part becoming loose, as is sometimes the case where columns and bolts and nuts are employed. The press ram is packed with hydraulic packing, which is easily accessible for replacement or tightening from the outside. The return motion is effected by means of two retractor pistons arranged laterally on the press cylinder, the pistons being connected with the press ram by a traverse guided on slide surfaces, which may be adjusted by suitable wedges.

An air vessel for prefilling with low pressure is located beside the main press, and is used to quicken the idle advance movement of the main ram, accumulator pressure being used only towards the end of stroke.


Position I.
Insertion of ingot or billet.
Position II.
Piercing and extrusion of billet.
Position III.
Lifting container with residual billet
Position IV.
Container in highest position.
Swing Saw
Insertion of press disc after charging with billet.
Lowest position of ram and mandrel when extruding.
Extrusion ram and mandrelin highest position. Cutting off residue.
Ejection of scrap end and the press disc.

Extruding methods when extruding with a movable mandrel.

The container into which the billet to be extruded is conveyed is inserted between the press ram and the lower part of the press frame, and vertical motion is imparted to it by two pistons, also arranged laterally on the press frame. When in its lowest position the container tightens against the die-holder located on the lowest section of frame, and in its top or uppermost position it leaves space between its lower face and the die for introduction of an electric-driven pendulum saw, which severs the extruded tube from the residue or pad of scrap left at the base of the container. Extrusion plants, similar in principle, are provided with a fixed container,* and in this case the severing of the residual pad, left in container at completion of the tube-extruding operation, is done by the introduction of a punch to which the power is applied. After severance the pad of scrap is drawn up out of the container on the return upward stroke of this appropriately shaped tool.

The Movable Container Type of Press.

The extruding die is mounted on a movable holder, which slides in a direction transverse to the direction of pressing, and can be brought by hand, when necessary, into a position for change of this important tool, which is removed from its holder by means of a small hydraulic ram. When the die-holder is thus placed away from the working centre of the press, the residual metal left in the entainer is pushed out clear by full extrusion pressure. A decided feature is the circular cutting-off saw previously mentioned. This tool is of the pendulum type, and swings to a working position in a horizontal direction.

Reference to the diagrams in Figs. 4 and 5 will indicate that these hydraulic plants, as applied to tube extrusion, are of two types—viz., Fig. 4 showing the operations with a movable mandrel, and Fig. 5 the operations with a fixed mandrel. In each case the progress of the operation is outlined.

Extrusion of Tubes by use of Movable Mandrel.

Position 1.—The ram with the mandrel is at its highest position. The container stands below on the die mandrel, so that between the mandrel and container the heated billet can be inserted in the latter. The pressing disc, as shown in bottom sketch, is then placed in position on top of the billet.

Position 2.—The ram and mandrel are moved by means of low pressure until the mandrel contacts with hot billet. At this point the accumulator pressure comes into operation to first pierce, and on completion of this stage to complete the extruding of a tube between the die and over the mandrel, the thickness of the shell being governed by the difference between the die and mandrel diameters divided by two—*e.g.*, die, $1\frac{3}{4}$ in. diameter; mandrel, $1\frac{1}{2}$ in. diameter; difference between these two diameters, $\frac{1}{4}$ in. Resultant tube $\frac{1}{8}$ in. wall thickness.

Position 3.—The ram and mandrel are drawn up to their highest position. The container is lifted only far enough to allow the saw to come into action between the container and the mandrel, so that it can sever the useful length of the shell from the pad or residual piece of the heated and pierced billet. The shell then glides down through the die and passes along the discharge channel, after which the saw is returned outwards to its original position.

Position 4.—The container is carried to its highest position, thereby bringing the pressing disc and residual piece of billet against the extended sleeve attached to the main ram which ejects them into the trough as shown. After the container is again lowered to its bottom position the plant is ready for the next operation.

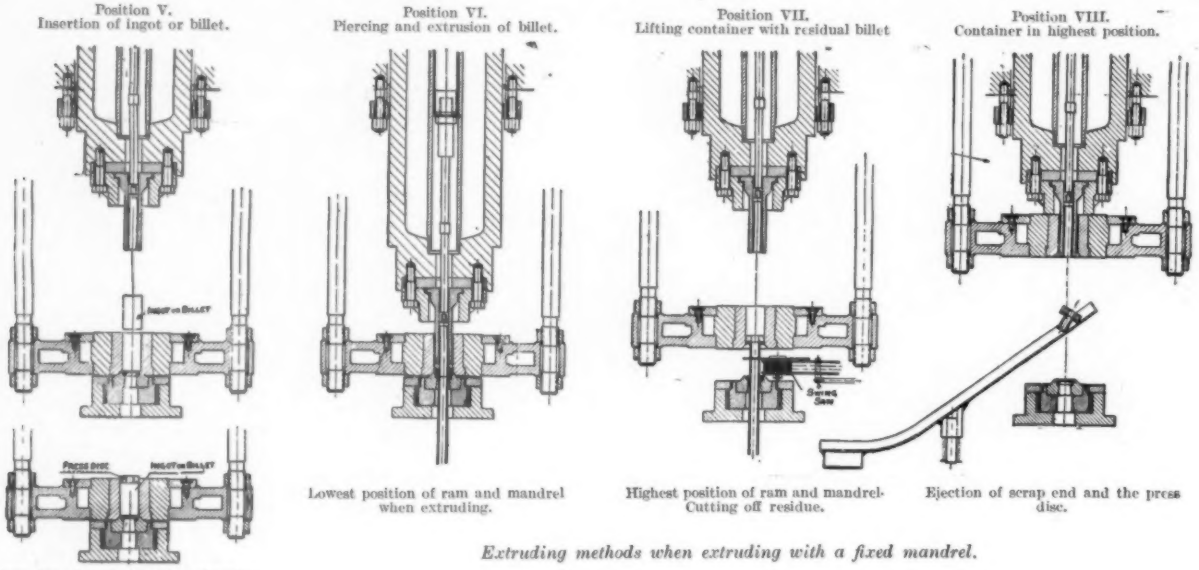
Extrusion of Tubes by Use of Fixed Mandrel.

Position 5.—The ram and mandrel are at their highest position, and the container stands below on the die mandrel, so that between the mandrel and the container the heated

* NOTE.—The author, owing to the amount of space available, has considered it necessary to confine his review to the movable container type of press as being sufficient for comparison with the method discussed in the fore part of this article.

billet can be inserted into the latter. The pressure disc, as shown in bottom sketch, is then placed in position on top of the billet. Note position of piercing and extruding mandrel.

Position 6.—The ram and mandrel are lowered jointly by means of low pressure until contacting with the heated billet, when the accumulator pressure is applied with similar effect as set out in Position 2, Positions 7 and 8. See descriptions at Positions 4 and 5.


Position V.
Insertion of ingot or billet.
Position VI.
Piercing and extrusion of billet.
Position VII.
Lifting container with residual billet
Position VIII.
Container in highest position.
Insertion of press disc after charging billet.
Lowest position of ram and mandrel when extruding.
Highest position of ram and mandrel. Cutting off residue.
Ejection of scrap end and the press disc.

Extruding methods when extruding with a fixed mandrel.

In conclusion, it may be mentioned that the extruding presses under review are of 600 tons capacity, and may be fixed either on the mill floor level, with suitable chamber built underneath or, alternatively, be erected on a raised platform, so that the extruded shell is delivered on to the ordinary working floor level. Other hydraulic presses for operating on metals and alloys of high tensile strengths are supplied, of ultimate working pressures up to 2,000 tons.

Having reviewed within the ambit of space at one's disposal the practical phases of rotary piercing and of extrusion of non-ferrous metals for the manufacture of tubes, one touches diffidently and briefly on the purely technical phases of the methods. Research by competent authorities reveals the fact that varying temperatures are essential to various alloys, inasmuch as a difference of 10° in the heating of the same material nearly doubles the velocity of extrusion through the same aperture. It is also recognised that different alloys are necessarily subjected to different velocities of extrusion, and this is a case in point where agreement between the technical and practical staffs probably leads to dependable and uniform results so necessary when viewed from the commercial aspect. The tabulated results of Jammann in this connection, although primarily applied to solids and sections, are worthy of study, as they are made over a wide field of material. It must be borne in mind, however, that the art of extruding as understood to-day is, comparatively, still in its infancy, the most marked developments having occurred since the end of the last century—viz., from non-ferrous rods to sections and tubes, and so on to steel of various qualities. The process has its limits in dealing with large diameters and weights, and one of the chief factors on which success depends is to what extent material under treatment for the production of tubes may be punished, or, in other words, the ratio of the pierced to the extruded shell.

The author reiterates his opinion that in a modern factory both the rotary piercer and the extruding press are essential, the former, when suitable material is provided, being necessary for large diameters, and the latter with its wider range in alloys for the smaller diameters. The rotary mill, with its great flexibility capable of dealing with sizes from 20 in. down to 2 in., has in some cases been duplicated with a reduction of peripheral speeds and decrease in power consumption when applied to billets of the smaller diameter* There is little economy in applying a mill with a capacity of 20 in. to billets of 4 in. and under. The outstanding costly factor in tubes of cold-drawn finish is the cold-drawing process, with its attendant pickling and annealing between each pass, but there are signs that in the near future the whole combined process will be reduced to a minimum, in fact to require just sufficient drawing to enable the material to comply with the mechanical or physical tests of standard specifications.

*[We understand the author is at present engaged in adapting, with every prospect of success, main working motors of variable speeds, with the object of adjusting peripheral speeds of working rolls to suit various alloys and solid billets of varying diameters, a development of considerable importance.—EDITOR.]

Tube Investments.

The directors of Tube Investments, Ltd., of Birmingham, announce that they have received the preliminary accounts of the subsidiary companies, which are all engaged in the tube-making trade, and that, subject to final audit, they will recommend a dividend of 8% on the ordinary shares and one at the relative rate on the liaison ordinary shares—which are held by Stewarts and Lloyds, Ltd.—for the year ending October 31 next. Dividends were paid at the same rates for the previous year and for the year before that, but for each of the six years to 1929-30, before the community of interests with Stewarts and Lloyds was arranged, 10% was paid. At the last annual meeting it was said that little or no corroboration could be found of the general belief that trade was on the turn, and it was stated that trade was still contracting slightly. Some evidence of improvement both in the iron and steel trades generally and in the tube-making trade in particular has taken place during the last few months, though the profits of the operating companies may not yet have expanded appreciably. The new undertaking for manufacturing steel for British tubes at Corby, in Lincolnshire, is an indication that the trade is looking forward with some confidence to better times, and accordingly the directors' report will be awaited with interest.

Messrs. Swan, Hunter, and Wigham-Richardson, Ltd., of Walker-on-Tyne, yesterday launched the collier *Sir Russell*, built for Messrs. Stephenson, Clarke, and Associated Companies, London. The vessel is 252 ft. long and 36 ft. beam. It is the third vessel launched in the Tyne this year.

British Export Trade with the Argentine

Suggested Modifications in British Standards for the Argentine Market.

ON February 24, 1932, the Secretary of the British Chamber of Commerce in the Argentine Republic addressed a letter to the Federation of British Industries in which several technical questions were raised regarding the standards of British products in comparison with other industrial countries, and suggesting modifications to meet the requirements of the Argentine market. The technical questions were referred to the British Standards Institution, the Engineering Divisional Council of which, recognising that the questions raised were of great importance to the British engineering export trade, gave instructions that it should be referred to the various Industry Committees of the Institution for consideration.

The three committees principally concerned were the Public Works, the Mechanical, and the Electrical Industry Committees, and they in turn referred the matter to the appropriate Technical Committees for consideration. In addition, various responsible trade organisations in this country were circularised, and inquiries as to the experience of certain British commercial agents elsewhere were made. The evidence collected is summarised in a reply which has been sent to the British Chamber of Commerce at Buenos Aires, from which it would appear that, on the whole, there would be very much to be gained by purchasers making use of British Standards and practices. The evidence shows that the reputation of British machinery has been built up on quality and durability, and that these characteristics have in the past proved effective from the point of view of sales. The following are extracts from the reply sent by the British Standards Institution :—

Electric Generators and Motors.—The correspondent quoted, who states that the British standard rating for industrial motors limits the temperature rise to 40° C., whereas the American and German allow 50° C., is correct. This, in fact, means that the British motor is 12—15% larger than the corresponding American or Continental machine. The question of bringing the British rating (40°) down to the American and German rating (50°) has been discussed for many years in this country and in numerous international meetings, but the great advantages of the British rating for motors for industrial purposes has always been maintained and would appear to have been established. The British motor has a very valuable overload capacity which, for industrial purposes, has proved a most desirable feature, and we have secured evidence to show that Continental manufacturers export motors to compete with British motors rated on the British basis. On the other hand, there are a number of British electrical manufacturers who modify the rating when necessary to compete with American or German machines.

Cranes, Derricks, Steel Structures, etc.—The committees responsible for the British Standard Specifications for cranes and derricks desire to point out that the policy adopted in preparing these specifications has been to provide factors of safety no higher than is necessary to provide adequate security in operation, thus making provision for cranes as light in weight as possible, having due regard to the use of British standard sections. Working to those standards a crane built to the limits laid down in the specifications would, therefore, be the lightest possible, consistent with proper protection to those using it and those working in its immediate neighbourhood. The criticism of your Chamber, however, has raised the important point as to whether the existing British standard sections might not have added to them certain other sections which would permit of the construction of cranes of adequate strength but of lesser weight, and this point will be carefully reviewed both from the design as well as from the economic point of view.

Your Chamber's report as to the crane which permitted of the excessive overload named, is difficult to deal with fully without some amplification, but it is clear to us that some cranes may have been supplied, for reasons which seemed adequate to the designer and manufacturer, which were somewhat heavier than the British standards allow as a minimum.

With regard to the transporter bridge, to which reference was made, we have ascertained that the English structure was designed to certain loads and conditions imposed by the authorities in the Argentine, and does not contain an excessive amount of steel for those loads. We are not aware as to the conditions under which the German structure was designed, and, in any event, we are advised that neither of them would conform to good engineering practice, as the span is too short for a proper transporter bridge.

In regard to bridge design, British practice may be said to have been on a somewhat generous basis, in the light of modern experimental evidence, and the British Standard Specification is being revised to provide for higher stresses than formerly.

The same may be said to apply to building structures. The new British Standard Specification for structural steel for use in buildings permits of a possible saving of some 20% in weight of material over previous home practice. British practice has been to a certain extent dominated by the conditions laid down for structural work in London, where the safety of the public and of other buildings has been the primary consideration and no risks could be taken.

During recent years a large amount of knowledge has been accumulated, and experimental work is still being carried out on an extensive scale, and it is probable that further revisions in the standards may be brought about. It is, however, by no means certain that much further weight reductions will ensue. It can, however, be safely asserted that lightening the weights by manufacturers in other countries has been based to a certain extent on an absence of exact knowledge, a knowledge which, in this country, has been gained at great expense.

Oil Engines.—Your Chamber's comment that British oil engines are rated at an output which is under their maximum, whereas our competitors have no margin, is a condition which could not be corrected by any British Standard Specification. An international committee is sitting discussing the basis for rating of oil engines, in which the British committee is participating. The work of this international committee will tend to diminish fictitious statements as to the capacity of oil engines. It is not anticipated that any of your associates would agree to the supply of an oil engine not capable of carrying continuously its rated output for 12 hours, and capable for periods of one hour of developing a load of 10% above its rated output without mechanical trouble. And that is the British rating.

Boilers.—In regard to boilers, your Chamber's attention is directed to the fact that British insurance rules for the design and construction of boilers compare very favourably with the American rules, but the Argentine rules for inspection of boilers specify a maximum life service at a particular steam pressure and temperature for every boiler, irrespective of its quality or condition. This rule is so obviously wrong technically as to suggest that the Argentine authorities might consider the preparation of rules for the construction of boilers so that quotations from different countries would be comparable. British Standard Specifications for the various types of boilers will shortly be available and these might be acceptable to the Argentine authorities.

Again, in this connection, whilst in the past it is probable that a good deal of inferior material has been supplied for export by manufacturing countries, it is believed that economic conditions are driving purchasers to take precautions to see that their money is being spent in the most efficient manner.

Refrigerating Compressors.—Your Chamber has gone into this matter in considerable detail, and the British makers have been much interested in the views expressed. They point out that some of the points of difference referred to are due to comparing the monobloc twin-cylinder designs with British multi-cylinder designs. In the former, a centre bearing between the cranks is not admissible, because the monobloc cylinder centres are so close together that they do not allow for it. It may be remembered that the British system of independent cylinders is more convenient for spares, and that in the multi-cylinder British designs, bearings between the cranks are essential with more than two cylinders, and desirable in any case, in order to give longer life and smoother running. The complete machining of crankshafts is adopted to ensure accurate balancing at high speeds. The machining might be reduced if the demands were sufficient to warrant the preparation of a British Standard Specification which would in itself, if widely used, so co-ordinate the users' requirements as to justify the cost of the dies for drop-forged cranks for small machines.

British makers appear to favour a standard two-bearing motor for these compressors, on the grounds of quick delivery and better support for the flywheel, which they consider desirable.

Your Chamber's observations as to cutting out unnecessary material and labour, and also as to relative weights of British machines and those of other countries, have been studied with interest by British makers and elicited detailed replies from them. It is not possible, in the compass of this letter, to set them out in detail, but it is claimed that the modern, high-speed, multi-cylinder machines of British construction would compare reasonably with the U.S.A. machines in weight, and that such difference as exists gives the British machines the advantages of better turning moment, more bearing surface, longer life, and smoother running.

Concrete Mixers and Road Machinery.—It is generally admitted that British road plant is heavier and better finished than foreign machinery, but the manufacturers in this country are unitedly of the opinion that customers in various parts of the world definitely expect a higher standard from British machinery and would be disappointed if they did not get it. The criticisms offered by your Chamber are being taken seriously into account by the British manufacturers, whose technical staff are reviewing the position. It is, however, pointed out that in general the American plant is bought in most cases just for the one job. The construction of the plant depends also on the rolled steel sections available. It would seem probable that, in the future, quotations based on plant of good quality, but with less attention paid to finish, will be available.

Motor-cars and Cycles.—This is a subject with which this Institution does not deal, the basis of the British horse-power rating being governed by legal statute for the purpose of taxation. It is probable that the remarkable fuel economy of the British car, and the improvement in the roads in all parts of the world, will tend to cause overseas purchasers to give preference to the British car notwithstanding the anomalies of its rating.

Air Compressors.—The best-known British makers of air compressors have studied the comments of your Chamber. It is unfortunately true that the British manufacturer who quotes on cubic feet of free air delivered is at a disadvantage if an uninformed buyer accepts the piston displacement as the measure of the air delivered by an air compressor. Years ago British makers were compelled to fight against this practice, and have so far succeeded that they do not consider, except in quite small machines, that this is a regular practice to-day.

I am asked to point out that no purchaser would, for example, buy a steam engine or an oil engine, on its piston displacement, and that it is the duty of salesmen to point out to the purchaser the obvious difference between displacement and the British makers' guarantee that the machine will actually deliver the volume of free air specified. It is considered that any return to the practice of quoting solely on piston displacement would be a retrograde and indefensible step, and that both users' and producers' interests would best be served by educating the buyer to insist on a guaranteed performance.

It would certainly be a wise step, at the present time, to give both the piston displacement and the guaranteed free air delivery, and, indeed, this is usually done. The expression "F.A.D." (free air delivered) is now being adopted in this country, and its definition is that it represents the "actual volume which the compressor will compress and deliver at the stated pressure expressed in cubic feet or cubic metres per minute at the intake and temperature and pressure." It is hoped that by persisting in the education of the buyer in this way, the expression "F.A.D." will become as common and well known abroad as the expression "B.H.P." for prime movers.

Valves.—Whilst accepting the statement that the British flanges for valves and pipes are heavier and that the bolt holes are more numerous, in the case of some material delivered to customers in Buenos Aires, a comparison of the British standards and practice with the U.S. practice shows, almost throughout the whole range of flanges, from low pressures up to the very highest pressures (1,400 lb. per square inch), that the British flanges are smaller in diameter and lighter in weight. In general, the number of bolt holes are the same, and, where different, the U.S. standards mentioned have generally larger bolt holes.

A detailed analysis is attached for the information of your Chamber.

General.—With regard to the suggestions for the adoption of the decimal system, and the relationship between the U.S. ton and the British ton, and your Chamber's proposals for the simplification of shipping documents, these have all been noted.

As a result, in all British Standard Specifications the use of the pound as well as the ton is being incorporated. With regard to gallons, the difference will certainly also be made clear. It would seem that the U.S. gallon could with advantage disappear, as the British gallon so happily fits any decimal calculations.

In submitting this reply, which has been based on a large mass of information, the Institution states that there is a good deal of evidence to justify the broad contention that the British standards of quality are higher than those of other countries. There is a good deal of evidence on the other hand to show that whilst in the past, low first cost may have been of prime importance, to-day more attention is being paid to the question of the real economic cost. Indeed, the cost of maintenance, breakdowns, and repairs are becoming of greater importance and more generally recognised. This is an aspect to which the special attention of your Chamber is drawn. It has to be remembered also that in many countries there is a growing practice of making rules and statutory regulations for the safety of workers and the public, which tend more and more to govern the construction of engineering equipment. There will, therefore, be an increasing tendency for British standards of quality to be adopted in which this aspect of the matter has had a considerable influence.

The question of introducing into British standard specifications different grades of quality for home and export is not a policy which is viewed with any favour.

The Committee extended a cordial invitation to the Chamber to take more direct advantage of the Local Committee of the Institution by appointing to it engineers familiar with and experienced in the industrial requirements of the Argentine. If they will then review the British Standard Specifications and send concrete proposals for any modifications which, from their wide knowledge of local conditions, would, in their opinion, tend to make these specifications more acceptable to purchasers in the Argentine, such proposals would, at once, be examined by the Technical Committee responsible for the particular specification under review.

New Refrigerator Motor-Ship.

The twin-screw motor-ship, *Port Chalmers*, 11,500 tons deadweight, was launched recently at Messrs. Swan, Hunter, and Wigham Richardson's yard, Wallsend, for the Commonwealth and Dominion Line.

This vessel has been specially designed and built for the dairy and fruit, and is one of the most improved type of refrigerator ships. Electric welding has been largely used in her construction, while her Diesel engines are designed to give a speed of 15½ knots. They were supplied by Messrs. Barclay, Curle and Co., Glasgow. It is expected that the ship will be ready for her maiden voyage early next January.

Oil from Coal

The various means of producing oil from coal were discussed by Dr. W. R. Ormandy and Dr. J. Burn at a meeting of the Institute of Marine Engineers on October 17, an abridgment of which is given in this article. The economic aspects were considered and a brief reference made to coal-oil mixtures.

THE prices and properties of the mineral oils with which the home-produced product will have to come into competition were briefly considered as a preliminary to discussing the oils produced by various means from coal. The present price of petrol in tank steamer lots is of the order of 3d. per gallon available for storage alongside British ports. At the moment casing head spirit, which is of a very light quality, and is used for mixing with cracked spirit to improve the starting properties, is hardly different in price from the heavier spirit to which it is added, but there is a measurable difference in price if the spirit on offer has an appreciably higher octane number than the average. Oils suitable for small compression-ignition engines and for use in gas-works for enriching water-gas are, if anything, dearer than petrol, whereas fuel oil is being put into bunkers at about £2 per ton. These exceedingly low prices are due, in the main, to the wasteful over-production which is now taking place all over the world. Prices are probably as low in England as in any country, as here there is a large open market which leads to competition between the various countries producing crude oil.

In so far as any process, using coal as a raw material, produces oil, there are grave difficulties in stating whether a process will be economic when the prices of the imported materials with which the coal product is competing are liable to sudden and considerable changes. The difficulty of the situation is enhanced by the fact that in almost all countries there are internal taxes which, in so far as they increase the cost of the petroleum products, are likely to make the possibilities of the home products appear rosier than they in fact are. In this country petrol, which costs about 3d. per gallon ex store, is subject to 8d. per gallon tax, and fuel oil, for most purposes, is subject to about £1 per ton. The Government may forgo part or the whole of the fuel tax to encourage home industry, but it is a risky matter to build up a large industry on such an unstable foundation.

The cost of distillation of coal and the capital cost of the plant employed, whether for high temperature, medium temperature, or low temperature carbonisation, can be determined within comparatively narrow limits, but these figures, under the economic conditions to-day, are of little value, for the incidence of taxation on all or some of their products may completely alter the possibilities of a process. The fact, too, that the prices of competing materials are liable to sudden changes at the will of politicians does not induce a sense of security.

The authors considered the production of oil from coal under three headings :—By straight distillation carried out over a wide range of temperatures ; by direct hydrogenation ; and by the distillation of coal and the conversion of the coke into water gas, which by catalytic reactions can be converted into a wide range of products, including oils.

Distillation at high temperatures is chiefly carried out in gasworks and in coke-ovens. On an average about 10 gals. of oils are obtained per ton of coal treated, and if the gases produced at the same time are stripped by means of oil washing or by activated carbon or similar methods, about 2 gals. of crude benzole are obtained. A certain percentage of the naphtha fraction is separated in the form of pure benzole and toluol for use in the chemical industry, but by far the greater portion is refined to a specific standard and is used as an ingredient in motor fuels. Owing to the high octane number of the motor benzole, it fetches a higher price in the open market than does petrol. At present this product, being entirely home produced, is not subject to the 8d. tax, as is imported petrol. Should this tax be imposed or should the price received for the motor benzole fall below 5d. or 6d. per gallon, it is a question whether the recovery of this product from the gases would be continued.

Out of the 10 gals. of heavy tar a number of products are obtained, such as anthracene, naphthalene, and creosote oil, but approximately one-half of the entire production is either employed at home or is exported abroad, in the form of prepared tar used in modern road construction.

At the present time the creosote oils are being produced at a rate in excess of the requirements of the legitimate market. If the steel industry were to grow to its former dimensions, with the consequent requirements for larger amounts of metallurgical coke, there would probably be a still greater excess production of a number of products, and it would appear that hydrogenation of these liquids for the production of a high grade motor fuel might be regarded as the most likely means for upgrading and marketing the products. Certainly there will be no attraction to either the gasworks or the coke-ovens to sell their products for use merely as a fuel in competition with the petroleum oils at the price of £2 per ton.

These high-temperature distillation products are merely by-products, and the amount which will be available is, therefore, dependent entirely upon the demand for the major products of the industries which make them. Even if a market for coal tar or its distillates had to be sought in competition with the imported fuel oils, regard would have to be paid to the fact that the creosote oils give out about 17,000 B.th.u.'s per lb., as compared with 19,000 B.th.u.'s obtainable from the imported competitor.

It was stated that no fraction of the high-temperature tars can be regarded as eminently suitable for use in compression-ignition engines. The very property of high spontaneous ignition which makes motor benzole so valuable in a spark-ignition motor militates against the use of the higher-boiling point fractions, with similar properties, in a compression-ignition engine.

Hydrogenation is an operation by which it is possible to convert practically the whole of the organic matter of the coal into liquid products. In principle, the operation is exceedingly simple. A suitable coal is ground to a powder of a fineness about equal to that used in coal-dust firing, and this dry powdered fuel is mixed with approximately its own weight of a heavy oil produced in a previous operation. This thick liquid mass is pumped into a pressure vessel where it is subjected to the action of hydrogen under high pressures varying from 150—250 atmospheres and at temperatures ranging from 350—520° C.

Under suitable conditions of temperature and pressure, Bergius found that many bituminous coals were converted as to 80 or 90% of their weight into a fairly thick liquid, which, by subsequent retreatment, could again be caused to take up more hydrogen with the production of comparatively low boiling liquids. Under these conditions the rate of absorption of the hydrogen in the Bergius experiments was too slow to enable the process to be worked economically. It is the discovery of catalytic bodies which hasten the union of the coal particles with the hydrogen which has brought the process nearer to the possibility of economic fruition. It has been found that the addition of comparatively minute quantities of certain metallic salts to the coal-oil mass to be hydrogenated results in a manifold increase in the rate of absorption of hydrogen, so that not only is the reaction hastened, but the conversion of the solid into a liquid is carried farther, with the resulting production of an increased amount of low boilers and a

thinning down of the heavy oils produced in the first treatment.

The products resulting from the first operation in the hydrogenation of coal can be subjected to further treatment, but in the presence of catalysts differing in type from those employed in the first operation, with the production of a petrol substitute amounting to 60% or thereabouts of the weight of the coal substance passing through the plant. The coal which has to be ground and treated under pressure in the hydrogenation plant should, of course, be well washed and the ash reduced to the absolute minimum, and most bituminous coals can be converted, for the most part, into petrol and heavier products.

Various claims have been made as to the total weight of coal necessary to produce a ton of petrol substitute. As little as 3 tons has been mentioned, and as high as 4, but obviously a great deal will depend upon the size of the unit employed in the process. Assuming the figure of 3½ tons of coal per ton of motor fuel produced, and assuming an average price of 12s. 6d. per ton of coal delivered to the works, this raw material alone amounts to £2 3s. 9d. per ton of petrol produced, and accepting that there are 300 gals. of petrol to the ton, the raw material costs alone amount to 1¾d. per gal. If the process be run for the production of fuel oils, the raw material costs per gallon of oil produced will only be slightly less than in the case of petrol.

It can definitely be said that it is to-day possible to convert bituminous coal, brown coal, or lignite into liquid products having a wide range of boiling points by means of hydrogenation. It has been widely stated that the hydrogenation of coal can only be carried out on a very large scale. At first the minimum scale for economic production was placed at 220,000 tons of petrol per annum. In South Africa, on the other hand, it was claimed that economic production could be obtained at 20,000—50,000 tons per annum. The present scheme, which is being developed by Imperial Chemical Industries Limited, is said to be on the scale of 100,000 tons per annum. As it is probable that the largest unit which can be employed in any plant will have a throughput of about 50 tons per day of coal-oil mixture, surprise may be expressed that no attempt has been made to put up, say, a three-unit plant with two units in action and one in reserve, in order that quantitative figures from industrial scale units might be obtained. On the other hand, the fact that Imperial Chemical Industries Limited are prepared, based on their own experimental work and that of their co-operators in Germany and America, to put down such a large unit in the first place is a measure of their confidence in their ability to overcome the technical difficulties which always arise in the first commercial unit of any plant.

It has been found that the gases produced by the distillation of coal, whether at high or low temperatures, can be converted into liquids having a wide range of boiling points and varying vastly in character. Attempts are being made to pass coke-oven and gasworks gaseous products over catalysts placed in a number of vessels worked in series. So far it cannot be said that these experiments have led to any large-scale commercial development, and having regard to the difficulties of finding out the exact conditions for high yields when dealing with comparatively pure chemicals this is no wonder. On the other hand, proposals have been made that the coke which is left on the distillation of coal should be converted into water gas with hydrogen into methanol, and, with altered catalyst and under other conditions, mixtures of higher alcohols have been produced. None of the work done in this connection, however, leads one to suppose that any immediate development along these lines is likely to lead to the production of comparatively cheap products of the nature of petrol and fuel oil.

A consideration of coal-oil mixtures was also given in view of its particular interest. The object of the development of coal-oil mixtures, the authors stated, is to produce a fuel with the inherent advantages of oil as regards handling, storage, and cleanliness, and at the same time to incorporate a percentage of home-produced fuel.

For a mixture of coal and oil to have the same mechanical advantages as oil, the coal must be present in a finely divided state, dispersed in the oil, and further, no separation of the coal due to settling must be stable. It is this question of stability which has given rise to difficulties in the development of coal-oil mixtures. Coal in a finely divided state contains approximately the same number of heat units per unit of volume as fuel oil, and, in general, for the same number of heat units coal is cheaper than fuel oils, so that the use of coal mixture is an economic proposition, provided that the cost of producing a stable coal-oil mixture does not outweigh the price advantage of coal on the thermal basis.

In so far as the application of coal-oil mixtures for steam-raising purposes is concerned, it is probable that such application will be confined to marine purposes where the handling and storage advantages are of prime importance and a liquid fuel enjoys a premium over a solid fuel. Fuel oil has no real advantages over coal or pulverised fuel for stationary steam raising plants except in a few isolated cases. This attitude, it is interesting to note, is taken not only by the coal producers, but is also recognised by some of the leading authorities in the oil world. Mr. J. B. Aug. Kessler, in his admirable lecture given at the recent World Petroleum Congress, deals at length with what he terms legitimate and illegitimate uses of oil, and he undoubtedly deprecates the forced sale of mineral oil for use where coal is obviously more suitable, having regard to economic factors. Further, the present uneconomically low prices for fuel oil are not likely to remain when the oil producers put their house in order and rationalise the output of crude oil.

New Coal Plant to be Erected in Yorkshire.

It is officially announced by the British Coal Refining Processes, Ltd., that their first plant will be erected on the outskirts of Huddersfield. Sources of coal supplies have been secured, together with sufficient land for future expansion. The B.C.R. process is founded on the Salerni system of low-temperature carbonisation, and is expected to revolutionise the scientific treatment of raw coal. Such highly successful results have been obtained on many different types of coal that it was decided to build this plant to demonstrate to the British coal industry the enormous economic and commercial possibilities of the process. It is confidently anticipated that the results of this private enterprise on the part of Sir Eric Hambro, the famous banker, will lead to the erection of large plants throughout all the coal areas in Great Britain, resulting not only in increased employment in the construction of plant and working of the process, but also in the coal mines.

Only 75% of the raw coal treated by this process becomes "refined" coal; therefore, when the present wasteful burning of raw coal becomes a thing of the past it will be necessary to mine fifty million tons of coal to supply the present domestic consumption of forty million tons. The company's technical experts are also studying the question of hydrogenating the oil obtained from the coal. The plant has been manufactured in this country under conditions of the closest secrecy, and the most modern ideas of engineering practice have been employed not only in the construction of the retort, but also in all accessories.

In an interview, Captain Allan Kyle, Managing Director of the company, said: "This is the outcome of three years' continual experiments and the results obtained in semi-industrial retorts. Nothing has been left to chance, and we are confident that the results of our first commercial plant will be a revelation to the coal industry."

Although Sir Eric Hambro only agreed to find the initial funds, he felt that no process in these times should seek the aid of the Government or even the public until it had proved itself an economical proposition on a commercial scale. He, therefore, has gone farther, and, with the help of a few enthusiastic friends, has enabled this commercial plant to be built.

METALLURGIA

The British Journal of Metals

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

Brighter Outlook in Trade.

Better Demand for Manufactures.

THE world has literally been starving itself in its production and consumption of steel for the past three years or so. Either the crisis must now become extreme and seriously affect our modern civilisation—which surely cannot happen—or there must soon be a great change for the better in the demand for steel of all types. This opinion was expressed by Sir Robert Hadfield when he welcomed members of the Iron and Steel Institute at the works of Messrs. Hadfields, Ltd., recently. There are surely distinct indications that a change is gradually taking place for the better not only with regard to the demand for steel of all types, but with practically every other basic commodity. Statistics show that during the last twelve months the number of unemployed persons has decreased by more than half a million. Full recovery must take time, but even to the most cautious, the gradual but persistent decline in unemployment must be acknowledged and appreciated. True, industry is still a long way from a condition commensurate with prosperity, but after the terrible depression so many industries have experienced, it is cheerful to realise that things are improving, and that many factors point to the improvement continuing.

It is of particular interest to note from the recent trade returns that the improvement is most marked in the staple industries which felt the effects of the depression to the greatest extent. Coal mining, for instance, shows an upward trend, the increasing demand for iron and steel has necessitated the employment of more people; the same applies to engineering and to the cotton and woollen industries. On the whole, the results achieved may reasonably be held to be reassuring. It is questionable of course whether the decline in the number of unemployed miners is really due entirely to the approach of winter, which naturally gives an impetus to coal raising or to general improvement in conditions; it is, however, a welcome sign. There are, of course, some industries which continue to remain in a deplorable condition. Notable of these is shipbuilding; but even in this industry encouraging signs appear in the returns. Not only does the total of merchant vessels under construction in Great Britain show a welcome increase over the preceding quarter of 16,260 tons, but it is 65,329 tons greater than the tonnage in hand a year ago. A slight improvement is also apparent in shipbuilding abroad and, for the first time in three and a half years, the world total of shipbuilding shows an increase of 24,257 tons.

Despite the fact that a few industries still languish, the general improvement in trade, which has been maintained for some time, shows that British industry is profiting from reconstruction schemes that are gradually being put into operation and is really progressing. It should be noted that the improvement is primarily due to home trade, and as Mr. Baldwin has pointed out, in time the home trade will reach saturation point beyond which it will be impossible to progress excepting by a definite revival in the export trade. This revival, however, depends upon the recovery of other countries to a more staple condition and to the removal of the many factors that hamper international trade. Fortunately, many of the European countries report decreases in the numbers of their unemployed, which indicates that the slight recovery experienced here is fairly general, in which case export trade will ultimately benefit.

In the strenuous efforts being made by all countries to win through the depression to prosperity, Great Britain is assuming a leading position. Just as a century ago she led the way to free trade on a competitive basis, so, to-day, she is giving a new lead by crystallising the modern trend to regulated or planned trade by means of bilateral treaties. This policy of trade agreements, commenced with the Ottawa Conference for the extension of British trade in Europe and South America, is being pushed steadily forward. Agreements have been entered into with Norway, Denmark, Sweden, Iceland, the Argentine, and one with Germany by which that country nearly doubles the quota of British coal in return for certain reductions in our tariff on German goods, while the more recent agreement, that with Finland, make the seventh of the series concluded during the past five months.

These agreements show two marked characteristics—the formation of regional groupings, as in the Ottawa agreements for instance, and the tendency to seek agreements for the fostering of complementary production. These modern forms of trade bargaining offer distinct scope for a freer interchange of goods or service, and it is in this direction that improvements in export trade lie. As yet the results of the Ottawa Agreements are not such as to warrant special rejoicing, but they may yet result in providing Dominion markets for British products on a scale comparable with the trade they enjoy with us. It is particularly gratifying that Australia has made such a wonderful recovery, which will ultimately have an influence on reciprocal trade. In regard to the foreign countries with which agreements have been reached, there are indications that these are being honoured, and the possibilities these markets present will tend to grow as world conditions become adjusted.

There is ample room for further agreements, and we are glad to note that the Federation of British Industries has included this as one of its recommendations to the Government. It states that the field of bilateral negotiations should be extended with such countries as are prepared to make reciprocally advantageous agreements with Great Britain for the mutual increase of trade. As a consequence of such bilateral agreements progress would be made towards the formation of a group of countries which were prepared to trade more freely between themselves, and thus to achieve some measure of exchange stability.

As a result of the progressiveness of managements that have reorganised with confidence to meet the new conditions, British producers are now in a better position to compete in the world's markets, and with continued effort, economy, and sacrifice fairly distributed among all concerned, the future can be faced with assurance. Trade is on the upgrade, but it must be borne in mind that increased consumption, upon which manufacturing countries like ours rely, is dependent upon the maintenance of the spirit of goodwill and co-operation. Peace and goodwill foster evolution, and so long as they predominate the process of industrial readaptation will proceed slowly, and given the right conditions will re-establish itself, and the demand for manufactured materials and articles for which the world is in need will increase and restore a condition of prosperity.

GREATER PERFECTION AT THE MOTOR SHOW.

ALL who visit the Motor Show at Olympia must marvel at the progress made in automobile construction in the comparatively short time since its inception. Each successive exhibition reveals the intense activity of this industry towards the production of more easily controlled and more serviceable cars, together with increase of comfort for drivers and passengers alike. Behind the brilliant show is the energy, ingenuity, and resourcefulness of an industry that is being appreciated more and more in the world's markets. These qualities, coupled with enterprise, have enabled Britain to lead the world in automobile construction, and explain to some degree why foreign markets are British motor-minded. Enterprise has helped this country to records for speed and endurance against competent rivals, and has opened many markets which are being secured by the quality and adaptation of the cars and motor vehicles supplied.

In some respects this year's show is more noteworthy than many that have been held. The modern motor-car is such a wonderful piece of mechanism that it is amazing how manufacturers can continue to effect improvements. Yet intense rivalry in the home market as well as abroad keeps manufacturers alive to the needs of the motoring public, as well as prospective motorists, who fear the intricacies of the mechanism they must control. It is to this latter section of the public that the show has a definite appeal, for it will be known as the show of easily driven cars. Cars equipped with easy change gears predominate. Several methods are shown. One of the most interesting is an automatic clutch controlled by centrifugal force; the arrangement is such that the drive is not taken up by the clutch until a certain engine speed is attained. The synchromesh gearbox is fitted on many models, while the pre-selector gearbox is a keen competitor. Both these silent gear-changing methods are a great improvement on the older type of gearbox and are easier to operate.

Although there is nothing of a revolutionary kind at Olympia, many of the models shown appear to have attained perfection in regard to design, workmanship, and appearance. Behind these exhibits of highly finished cars, there is constant striving for reliability. In this direction great progress has been achieved, and it provides one of the main factors that has gained for British cars world-wide reputation. To secure the high degree of reliability now recognised has involved ceaseless investigation and trial under most exacting conditions. In practically every instance extensive and prolonged road tests are carried out, and the effect on parts is carefully checked with a view to the elimination of possible defects. In this way the material finally selected for a particular part is not only carefully analysed and tested in the laboratory, but is subjected to road tests more severe than are likely to be encountered in normal use. Metallurgical developments have also contributed to the greater reliability of British motor-cars, more particularly in the care being exercised in standardising the composition of those alloys which have been found to be the best to resist the stresses of the various parts, and in determining the correct heat-treatment, where this is necessary, so that parts can be duplicated with similar characteristics within very fine limits. It is on this important feature of reliability that the reputation of British automobile engineering ultimately rests, and we are confident that manufacturers will strive to maintain and add to the prestige already gained.

MANCHESTER METALLURGICAL SOCIETY.

Oct. 25. Joint meeting with the Institute of Metals to discuss the following papers, presented at the recent annual meeting at Birmingham.
(a) "Experiments in Wire-Drawing," Part III.
(b) "Observations on the Distribution of Porosity in Aluminium and Copper Ingots,"

Forthcoming Meetings

Nov. 3. Thomas Hawksley Lecture by Professor A. F. C. Pollard. Subject: "Kinematic Design in Engineering."

GRADUATES' SECTION (LONDON).

Oct. 30. "Stainless Steels in Aeroplane Structures," by F. J. Murdoch, B.Sc.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Nov. 3. Andrew Laing Lecture by Professor F. C. Lea, O.B.E., D.Sc. Subject: "Recent Metallurgical Developments and their Significance for Shipbuilding and Marine Engineering."

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Oct. 24. "Flame Cutting of Steel for Welded Joints," by E. J. Clarke.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Nov. 7. "Interpretation of a Photomicrograph," by J. W. Jones, M.Sc.

LONDON SECTION.

Nov. 9. "Gold—Its Sources and Production," by R. Annan.
Meeting to be held at the Royal School of Mines, at 8 p.m.

NORTH-EAST COAST SECTION.

Nov. 14. "Metal Spraying," by W. E. Ballard.
Joint meeting with the Newcastle branch of the Society of Chemical Industry.

SCOTTISH SECTION.

Nov. 13. Discussion of papers presented at the Autumn Meeting of the Institute.

SHEFFIELD SECTION.

Nov. 10. "Metal Spraying," by W. E. Ballard.

SWANSEA SECTION.

Nov. 14. "Ageing and Age-Hardening," by Cecil H. Desch, D.Sc., Ph.D., F.R.S.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM AND WEST MIDLANDS BRANCH.

Oct. 26. Discussion: "The Production of Sound Iron Castings."
Joint meeting with Midland Metallurgical Societies.

Nov. 2. "The Education of Foundry Workers," by Prof. J. H. Andrews, D.Sc.

EAST MIDLANDS BRANCH.

Oct. 28. "Technical Control in the Small Foundry," by J. G. Pearce, M.Sc.

LANCASHIRE BRANCH.

Nov. 4. "Continuous Casting Plant," by J. Cook. Films will be shown.

PRESTON SECTION.

Nov. 1. "The Manufacture and Application of Centrifugal Castings," by T. R. Twigger.

LONDON BRANCH.

Nov. 1. "Cupola Practice," by L. W. Bolton.

MIDDLESBROUGH BRANCH.

Oct. 27. "Contraction, Distortion, and Camber in Grey Iron Castings," by E. Longden.

Nov. 10. "Routine Methods of Testing Green Sands," by N. D. Ridsdale, F.C.S.

NEWCASTLE-ON-TYNE AND DISTRICT BRANCH.

Oct. 28. (1) Presidential Address by J. D. Carmichael, O.B.E.
(2) "The Building of the Sydney Harbour Bridge."
(*Illustrated by cinematograph film.*)

SCOTTISH BRANCH.

Oct. 28. "Gray Iron Castings for Laundry Machinery," by J. Longden.

Nov. 11. "Cast Iron and Its Physical Characteristics," by W. McDougall.

SHEFFIELD AND DISTRICT BRANCH.

Oct. 20. "Stainless and Heat-resisting Steels," by J. F. Kayser.

WALES AND MONMOUTH BRANCH.

Oct. 21. "Some Practical Considerations in a Small Jobbing Foundry," by B. Gale.

Nov. 11. "Foundry Mechanisation," by A. S. Beech.

Blast-Furnace Gas Cleaning

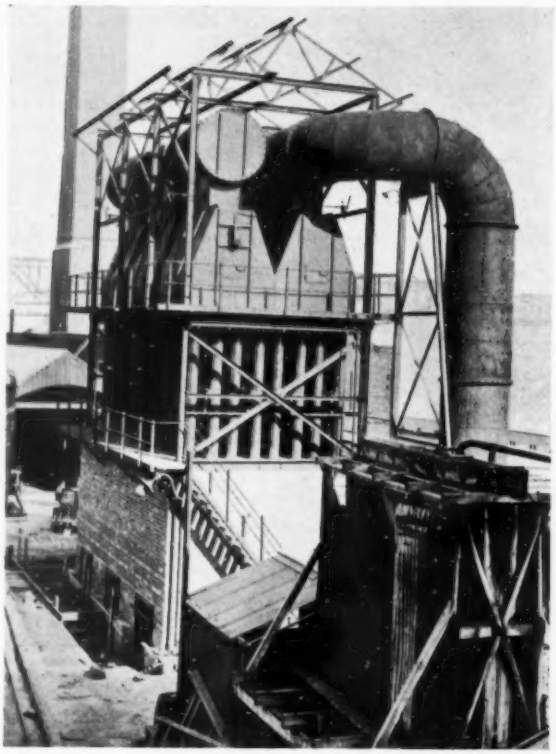
The blast-furnace gas-cleaning plant at the Corby Works is to be extended, and the gas instead of being rough-cleaned as formerly will be thoroughly cleaned, in order that it can be used for heating the by-product coke-ovens, as well as mixing with coke-oven gas for use in the steelworks.

GREAT interest attaches to a "Lodge-Cottrell" electrostatic precipitation plant for the cleaning of the blast-furnace gas that is being installed for Messrs. Stewart and Lloyds, Ltd., at Corby. This is an extension of the equipment already supplied by Messrs. Lodge-Cottrell, Ltd., of Birmingham, some six years ago, for the rough cleaning of the blast-furnace gas, to suit the then existing conditions.

Now, however, all the gas is to be used, not only in modern stoves, with close fireclay packing, but also for heating the by-product coke-ovens in place of rich coke-oven gas, as well as for mixing with the latter for use in the steelworks. Consequently, a thorough cleaning of the blast-furnace gas is necessary, and for this reason the existing electrostatic equipment is being supplemented so as to form a two-stage installation on the latest scientific principles.

The total capacity of the complete plant will be 5,500,000 cub. ft. of gas per hour (normal temperature and pressure), which will be cleaned down to the guaranteed figure of only 0·0068 grains of dust per cub. ft. (0.02 grms. per cubic metre). In general the original rough cleaner will bring down the bulk of the dust—well over 90%—in the dry state, and the gases will then pass on to conditioning and cooling towers before receiving their second electrical treatment. This will eliminate the remainder of the dust and all water mist, so that the gas will pass on clean, cool, and dry, while the net amount of water required is very small, the total volume being constantly re-circulated and the sludge removed.

It will be remembered the basic principle of the process, primarily the invention of Sir Oliver Lodge (Great Britain), Dr. F. G. Cottrell (U.S.A.), and Dr. Erwin Moller (Germany), consists in the use of concrete chambers or towers through which the dust or fume-laden gases are passed. In these towers is a series of vertical metal plates or pipes, forming collector electrodes, which are connected to the earth. In the narrow spaces between these plates, or in the pipes, hang wires or rods with numerous points constituting discharge electrodes, which are coupled to very high tension direct-current supply at 60,000–70,000 volts, so that brush discharge takes place, giving a flow of light or corona, and creating a powerful electrostatic field. This high tension current is produced by stepping-up ordinary low-tension supply in a transformer, and then converting to direct current by a motor-driven rectifier.



Typical "Lodge-Cottrell" gas-cleaning plant on the latest two-stage principle, cleaning to 0·0068 grains of dust or less per cub. ft.

As the gases pass through the electrostatic field, all the solid or liquid particles are electrified and repelled against the earthed collector electrodes—that is, the pipes or plates. Here they give up their charge and fall down to the bottom of the tower into a hopper, or partly adhere to the collector plates, the latter being equipped for this reason with motor-driven rapping hammers.

The different companies concerned, in Great Britain, the United States, and Germany, six in number, have now closely co-operated for several years, pooling all their patents and experience, and as a result considerable improvements have been effected in the process.

It is important to note also that electrostatic precipitation for blast-furnace gas, especially on the new two-stage principle, is not only very much more efficient, but also cheaper in operation than either bag filters or disintegrators, using forced water sprays.

A huge new field now opening up also is the separation of the dust from combustion gases, especially in power stations fired with pulverised fuel, and significant is the fact that both the Hams Hall and Nechells power stations of the Birmingham Corporation are now to be equipped with "Lodge-Cottrell" plants, while over forty power stations, including Willesden, in London, are already running with great success in various countries.

Original rough cleaning plant at Corby, now to be extended to the two-stage principle for very fine cleaning.

Some Investigations and Observations Principally on the Strength Properties of Cast Iron

By J. E. Hurst.

The production of castings with the maximum degree of uniformity is very difficult in ordinary foundry practice, and this article is the first of a series of investigations in an endeavour to promote greater uniformity in regard to strength properties.

IN the course of continuous connection with a complex material like cast iron numerous investigations and experiments have been made with only a limited object in view. Such investigations are described conveniently as minor experiments, for whilst in many cases they touch upon larger issues and obviously demand further continuance of the investigations, this has not been done in most cases when it was found that the immediate object had been satisfied. Most of these experiments have been recorded carefully, and are of particular interest in view of the fact that they have been made on material produced under carefully controlled conditions. For the most part, the investigations have been made in the course of the preparation of castings, both sand cast and centrifugally cast, for piston-ring drums, an industry which for some years now has insisted upon the most stringent precautions being taken with the underlying object of obtaining the highest possible degree of continued uniformity in the material and its properties. In this industry it is now normal for the casting conditions to be carefully controlled, and the production of such castings is made to the requirements of B.S.I. and aircraft material specifications. The chemical composition of this material, strictly limited as it is by specification, varies only between very close limits, and furthermore the method of conducting the mechanical tests both for control and acceptance purposes utilises test-pieces of small and extremely accurate dimensions, for which reason they are undoubtedly of a higher degree of sensitivity than those usually adopted in the commercial examination of cast iron.

In endeavouring to produce castings having the maximum possible degree of uniformity in properties from day to day, it is natural to proceed by way of obtaining strictly uniform chemical composition. In ordinary foundry practice, using the cupola as a melting unit, precision in this respect is astonishingly difficult, as the following records show. The mixture used in these experiments conducted some years ago was composed of low silicon hematite pig iron, high silicon phosphoric foundry iron, and returned scrap only. The mixture was charged into the cupola in charges weighing 2½ cwt. each, and the molten metal tapped out in similar quantities of 2½ cwt. This molten metal was used for pouring individual castings of weights varying from about 6 lb. to 12 lb. each. A number of chemical analyses of castings taken from one day's cast are set out in the accompanying Table I.

TABLE I.

Casting No.	1.	2.	3.	4.	5.	6.
Total carbon .... %	3·18	3·54	3·34	3·56	3·11	3·39
Combined carbon .. %	0·59	0·71	0·57	0·63	0·53	0·60
Graphite ..... %	2·59	2·83	2·77	2·93	2·58	2·79
Silicon ..... %	2·08	1·72	1·98	1·66	2·26	2·26
Manganese ..... %	0·54	0·54	0·58	0·82	0·71	0·59
Sulphur ..... %	0·06	0·06	0·05	0·06	0·05	0·06
Phosphorus ..... %	0·46	0·19	0·53	0·19	0·78	0·80

These castings were produced throughout the day in succession in the order as indicated by the casting numbers. An examination of the results shows variations in the compositions. Total carbons vary from 3·11% to 3·54%; combined carbon from 0·53% to 0·71%; graphite from 2·58% to 2·83%; silicon from 1·66% to 2·26%; manganese 0·54% to 0·82%; phosphorus from 0·17% to 0·80%, and sulphur is the only element in which it can be truly said that the variation is negligible. It will be noticed that these variations in composition have persisted in spite of the fact that the tappings of molten metal are equivalent in weight to the weight of one charge. The experiment is sufficient to demonstrate clearly the difficulty of obtaining exact uniformity of composition under these conditions. The lack of uniformity in composition is accompanied by a similar lack in uniformity of the physical properties. The extent of this can be judged from the test results from the same castings displayed in Table II.

TABLE II.

Casting Number	1.	2.	3.	4.	5.	6.
Brinell Hardness— 10/3,000/	223	235	217	241	212	235
Tensile strength, tons per sq. in.	18·6	22·4	19·2	23·2	20·1	17·8
E N value, lb. per sq. in. × 10^6	16·8	14·3	15·9	13·8	16·9	17·0
Permanent set, % ...	15·6	18·3	14·2	17·8	10·5	11·1

It is evident even with stringent laboratory control of the composition that, unless special steps are taken, the difficulty of obtaining uniformity is very great. Either of two methods are available, the first of which relies on the collection of the molten metal from the cupola in a receiver of sufficiently large capacity. It is necessary generally for such receivers to be oil-fired or otherwise heated to maintain the temperature of the molten metal. The alternative method involves the preparation of the mixture, utilising a refined iron of guaranteed composition and returned scrap only. The composition of the refined iron must be adjusted to make sufficient allowance for melting losses in silicon and manganese. Such refined irons, in which the guaranteed composition can be relied upon are available, and the use of this method avoids the necessity for using components in the mixture of widely different compositions. Both these methods are now in use, with a consequent improvement in the degree of uniformity.

The requirements of the B.S.I. specifications for piston-ring material include a specified value for the modulus of elasticity or more strictly the E N value. The modulus of elasticity is an attribute of the strength properties not met with commonly in ordinary commercial testing of cast iron. In a perfectly elastic material the strain produced when it is subject to stress disappears entirely when the stress is removed, providing, of course, the stress has not exceeded in magnitude a critical value which is present in most materials and known as the elastic limit. The magnitude of the strain is found to bear a relation to the stress producing it, in such a manner that the intensity of stress = strain × constant.

This constant is known as the modulus of elasticity or the stretch modulus. The strain, although numerically equal to the stretch per unit length in tensile stress conditions, is measured as a mere number. Therefore the constant or the

modulus of elasticity in the above relationship is a quantity of the same kind as the stress intensity, and is measured in units of force per unit area. This modulus is commonly expressed in terms of pounds or tons per sq. in. Using instruments of sufficient precision, most industrial materials show slight permanent strains, even with low values of stress intensity. This departure from the strict definition of elastic material is particularly true in materials which never have been stressed previously, and in materials in the "as cast" condition. Neglecting very small permanent strains, the materials wrought iron and steel can be said to be truly elastic over a range of stress, and throughout this elastic range the proportionality in the above equation remains constant. Cast iron is different from wrought iron and steel, in that it possesses generally no well-defined elastic range in which the above proportionality holds. Different observers have reported that whatever traces of an elastic limit there are in cast iron occur at very low stress values, and such values are given as from 0·45 to 0·80% of the ultimate load. It is generally considered that for cast iron there is no indication of an elastic range, and the stress/strain relationship is not constant; the strain increasing in magnitude with increasing stress. The load/extension or stress/strain diagrams for cast iron are consequently curved from the origin, and the numerical value of the modulus of elasticity thus varies with the intensity of stress, being higher with low stress values and smaller at the high stress values.

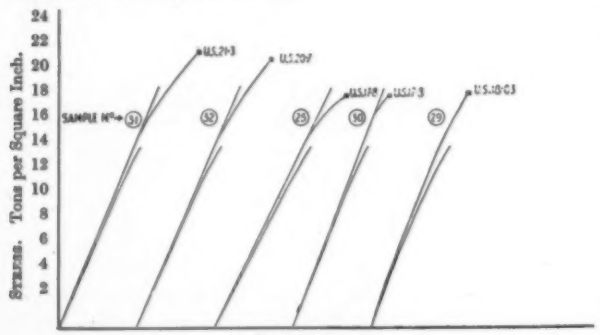


Fig. 1.—Stress-deflection curves on specimens described in Table III.

Various suggestions have been made to develop equations for the type of load extension curve presented by cast iron, and equations of both exponential and hyperbolic form have been proposed. From the point of view of commercial testing, the difficulties of strict definition have been met by carefully defining the conditions of the test under which the modulus of elasticity is determined; hence the use of the designation E N in place of the usual E for this property in the B.S.I. specification referred to above.

Strictly, these general remarks refer to grey cast iron. White irons appear to behave somewhat differently. Generally, white irons yield stress/strain curves which are practically straight, indicating close approximation to conditions of true proportionality right up to the breaking load. Similarly, grey irons in the quench-hardened condition (martensitic) prior to tempering yield curves of the same type. The former, in general, have a very high value for the modulus of elasticity, and experience seems to show broadly that those grey cast irons which possess high E N values approach more nearly to conditions of true elasticity over quite a substantial stress range. In fact, stress/strain curves of such cast irons appear to reveal traces of proportionality at stress values of at least 50% and over of the breaking stress. Centrifugally cast grey iron almost invariably possesses a higher modulus of elasticity than sand-cast grey iron, and the stress/strain curves quite frequently disclose these proportionality characteristics. As an example of this, the series of curves illustrated in Fig. 1 are typical, and the middle three curves quite clearly show traces of a limit of proportionality. The chemical composition and properties of these specimens are given in Table III.

TABLE III.

Sample Number.	Total Carbon, %.	Combined Carbon, %.	Graphite, %.	Silicon, %.	Manganese, %.	Sulphur, %.	Phosphorus, %.	Ultimate Strength, Tons per Sq. In.	E N Value, Lb. per Sq. In.	Areas of Stress Deflection Curve.	Limit of Proportionality, Tons per Sq. In.	Permanent Set, %.	Brinell Hardness.
31	3·55	0·95	2·60	2·47	0·42	0·032	1·32	21·28	16·9	33·15	—	11·15	269
32	3·93	0·39	3·54	2·25	0·44	0·083	1·56	20·7	17·5	30·97	13	9·25	286
25	3·60	0·26	3·34	3·90	0·33	0·026	1·92	17·8	16·9	25·85	12	9·45	255
30	3·71	0·52	3·19	2·70	0·96	0·022	1·65	17·8	18·0	18·03	14	7·6	205
29	2·89	0·09	2·80	3·34	0·35	0·022	1·73	18·2	18·5	18·53	—	10·15	209

(*To be continued.*)

British Exhibition Trains.

A type of trade exhibition which is new to Great Britain is to be launched in the early spring. It is to be housed in a railway train which will tour the railway system of the country, halting at convenient stations for traders and public to inspect the goods. A train composed of 17 corridor coaches is being adapted to house 100 to 150 exhibits. There will be a luxuriously equipped reception coach, a dining car, and a coach carrying the electric lighting and power plant.

The organisers are British and Dominions Travelling Exhibitions, Ltd., and the chairman is Mr. Leopold Walford, head of an old-established London shipping and transport firm. Mr. Walford has secured the warm co-operation of the British railway companies, and the technical help of the organisers of similar exhibition trains which have been running successfully for some time on the Continent.

So many traders in outlying parts find it difficult to visit the great industrial fairs, says Mr. Walford, that the idea has been conceived of taking a representative exhibition to their very doorsteps, thus supplementing the work already done by distributing agents and travellers. An exhibition train on the Continent, which is known as the "Orange Train," has just completed a three-months' tour of Holland, and during that time it has attracted 405,000 visitors.

The first "Buy British" exhibition train will leave Birmingham on March 14, returning there on June 15 after a circular tour of the southern half of England. Over sixty stopping places have been arranged, including Wolverhampton, Newport, Cardiff, Bristol, Exeter, Plymouth, Bournemouth, Southampton, Brighton, Folkestone, Maidstone, Redhill, Paddington, Ipswich, Norwich, Cambridge, Lincoln, Nottingham, Derby, Manchester, Liverpool, and Crewe.

The starting date has been chosen for the convenience of exhibitors at the British Industries Fair, who will be able to transfer their goods straight from the Fair into the "travelling shop window," and so have a second display under novel and attractive conditions in industrial, agricultural, mining and seaside districts. Civic authorities at each stopping-place are to be invited to attend the official opening of the exhibition. Traders will receive invitations, and the general public will be admitted at a small fee during certain hours. Salesmen will be in charge of the stands for the purpose of booking orders, but although samples may be distributed no retail trading will be done.

An itinerary is being agreed upon for a second train to tour the North of England and Scotland in the autumn of 1934, and, later, it is proposed to arrange for trains to tour the Dominions. Plans are also being worked out for a continental tour for a British exhibition train, beginning in Belgium at the end of March next.

Nickel-Chromium Resistance Alloys and their Life Test

By W. Hessenbruch and W. Rohn.

Various methods of testing nickel-chromium alloys are critically discussed, and a method for the life test, giving results in agreement with practical experience, is described. It is shown that the temperature must be kept constant during the test, and that the alteration in resistance gives valuable information as to the behaviour of the wire. The influence of various elements on the life of iron and nickel was investigated. Chromium and silicon (also molybdenum) increased it, carbon decreased it. Widely different nickel-chromium alloys were also investigated. The influence of temperature, atmosphere, and certain surface treatments is described. Metallurgical treatment during production and treatment during fabrication determine the value of the alloy, and recent research on these lines results in the production of a nickel-chromium alloy with about twice the life of already-known alloys. Finally, the scaling process is followed metallographically, and the significance of grain boundaries and segregations discussed.

THE oxidation of metals at high temperatures has been comparatively little studied. As often happens, technique outstripped research and produced wires sufficiently resistant to oxidation at high temperatures to be used for heating elements, especially as, compared with pure metals, their specific resistance was high. Two groups of alloys were produced—(*a*) 15% chromium, 20–25% iron, rest nickel; and (*b*) 20% chromium, 80% nickel, both with small amounts of manganese and silicon. Additions of Al, Si, Mo, Wo, and Cu were also made, the type of alloy remaining unaltered.

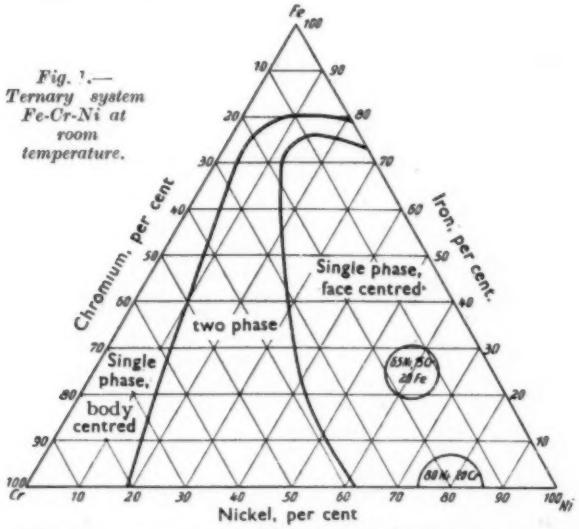


Fig. 1.—Ternary system Fe-Cr-Ni at room temperature.

The crystal structure of nickel and chromium is regular, but nickel has a face-centred lattice, chromium a body-centred. Iron is likewise regular, but exists in both the surface-centred γ-state and the cube-centred α- or δ-state. These facts determine the structure of the alloys. At room temperature nickel holds about 38% chromium in solid solution, and still remains surface-centred. Conversely, chromium holds about 18% nickel in solid solution, still remaining cube-centred. Between these concentrations there is a heterogeneous range of little value owing to the difficulty of cold-working. Addition of iron narrows the range somewhat. Fig. 1 shows the ternary system Cr-Fe-Ni at room temperature.[1] The cube-centred alloys on the Cr side are difficult to work, and have apparently no advantage in heat resistance over the surface-centred austenitic alloys on the Ni-Fe side. The two chief classes—65% Ni, 20% Fe, 15% Cr, and 80% Ni, 20% Cr—are thus austenitic, undergo no phase transition, and can be worked and rolled hot and cold.

The iron-free alloys have generally a longer life than those containing iron. Systematic investigation of the influence of other elements was difficult owing to lack of a satisfactory test for heat resistance. Most tests so little reproduce practical conditions that results are of no value.

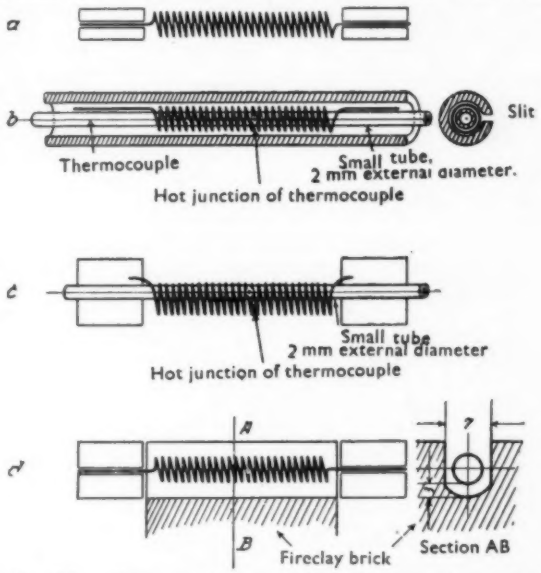


Fig. 2.—Schematic representation of various scaling test procedures.
(*a*) *Original Smithells' procedure.* (*c*) *With inner tube.*
(*b*) *With outer and inner tube.* (*d*) *With fireclay slot.*

II.—Determination of the Life of Nickel-Chromium Alloys by Scaling Experiments.

In some cases resistance to scaling was determined from the increase in weight after a definite heating, either directly (thermo-balance)[2] or indirectly (weighing before and after).[3] In other cases the amount of scale flaked off per unit area or removed by mechanical treatment is determined.[4] The increase in the resistance of a wire after treatment at high temperatures has also been used to determine the resistance to oxidation.[5] In recent years methods for directly determining the life by heating at high temperatures have been introduced.[6] All suffer from the faults already mentioned. The most useful are those which determine the life at the temperature at which the wire is to be used, those of Smithells, Williams, and Avery,[5] and Bash and Harsh,[6] deserving special mention.

* Abstracted from "Hochwertige Chrom-Nickel-Legierungen und deren Lebens, dauerprüefung," *Heraeus Vacuum-Schmelze.* Edited by Dr. W. Rohn. 1923-1933-p. 247.

† "Widerstandslegierung für Temperaturen bis 1,300° C.," *Heraeus Vacuum-Schmelze.* 1923–1933, p. 169.

1 F. Wever and W. Jellinghaus, "Das Dreistoffsystem Eisen-Chrom-Nickel," *Mitt. Kaiser Wilhelm Inst. f. Eisenforsch,* vol. 13 (1931), pp. 93-108.

2 Y. Utida and M. Saito, "The Oxydation of Metals and Alloys at High Temperatures," *Science Rep. Tohoku, Imp. Univ.,* vol. 13 (1924-5), pp. 391-9. W. H. Hatfield, "Heat Resisting Steels," *J. Iron Steel Inst.,* vol. 115 (1927), p. 483.

3 M. Horicka, K. Yamamoto, and K. Honda, "On the Life of Resistance Wires for Electric Heating," *Res. Electrot. Labor. Tokyo, No.* 307 (1931) *Phys. Ber.,* vol. 12 (1931), p. 2,588.

4 W. Rohn, "Vergleichende Untersuchungen über die Oxydation von Cr-Ni-Legierungen bei hohen Temperaturen," *E.T.Z.,* vol. 48 (1927), pp. 227 and 317.

5 C. J. Smithells, S. V. Williams, and J. W. Avery, "Laboratory Experiments on High Temperature Resistance Alloys," *J. Inst. Met.,* vol. 40 (1928), p. 269.

6 F. E. Bash and J. W. Harsch, "Life Tests on Metallic Resistor Materials for Electrical Heating," *Proc. Amer. Soc. Test. Mat.,* vol. 29 (1929), No. II, p. 506.

In the first of these a freely hanging horizontal spiral, 25 mm. long and 3·2 mm. internal diameter, with a pitch of 1 mm., made from wire 0·375 mm. diameter, is heated at 900° or 1,000° C., with an intermittency of 2 mins. till it burns through. The initial voltage required to give the desired temperature is maintained throughout the test, the temperature falling off to an indefinite extent.

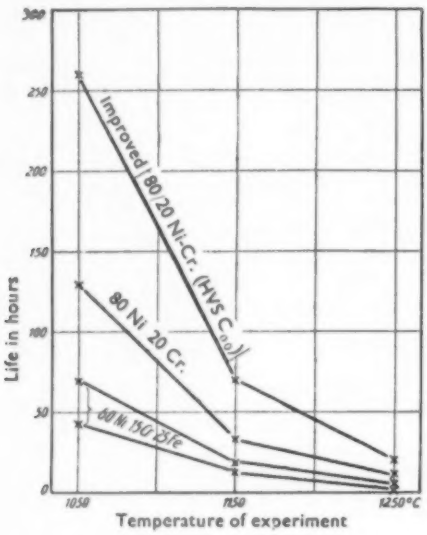


Fig. 3.—Influence of temperature on the life of Nickel-chromium.

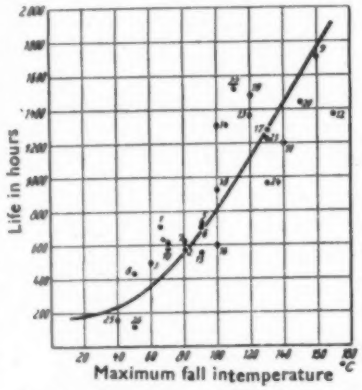


Fig. 4.—Dependence of life of Ni-Cr alloys of the 80/20 class on fall in temperature (initial temperature 1,050° C.).

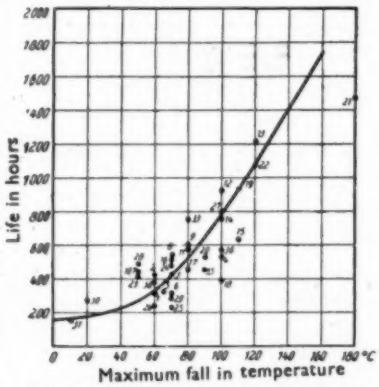


Fig. 5.—Dependence of life of Ni-Cr alloys of the 65/15/20 Ni-Cr-Fe class on fall in temperature (initial temperature 1,050° C.).

In the second, the wire is suspended with its lower end in mercury, through which the current is supplied. The initial temperature is regulated, and the wire alternately switched on and off for 20 mins., either the temperature or the voltage being kept constant. The life and the rise in the resistance are taken as a measure of the value of the alloy.

The contradictory results sometimes given by Smithells' method are due to sagging or distortion, so that individual turns touch each other, which is impossible in actual practice, the spiral being placed on refractory material. To simulate practical conditions, in some cases the spirals were placed in a small alumina tube provided with a 1 mm. slit for temperature control. In another series the spiral was also supported internally by a smaller tube. The alteration in temperature could thus be measured with a fine thermo-couple placed inside the small tube. To determine the effect of reduced speed of cooling and heating with intermittent heating as in actual practice, the spiral, supported on a small tube, was placed in an open-topped channel in a fireclay brick, out of contact with it. These various arrangements are shown in Fig. 2, the important dimensions being given.

Table I. gives the results of tests on various materials and shows how the experimental conditions influence the results.

The numbers in brackets indicate the order of merit of the alloys, and it is evident that this depends on the procedure. The gradual fall in temperature differs from alloy to alloy, and one alloy may for most of the test be at a much lower temperature than another. Individual results by the same method also vary greatly, so that none of these methods is suitable as a standard test.

The oxidation, and therefore life, of a nickel-chromium wire is largely dependent on the temperature. Fig. 3 shows the dependence of the life on the initial temperature for two technically important alloys—80% Ni, 20% Cr, and 65% Ni, 15% Cr, 20% Fe,—and an improved alloy of the 80/20 class, obtained by special treatment, a method of testing described later having been used. The life at 1,150° C. is only one-third that at 1,050° C., whilst at 1,250° C. it is only one-thirteenth. The part played by differing falls in temperature is obvious, and is emphasised by Figs. 4 and 5, in which the alloys having the greatest fall in temperature show the longest life. There are also differences in test-pieces giving the same fall, due to different additions to the basic alloy or to metallurgical treatments.

Differences in fall in temperature are also due to the fact that at constant voltage the greater the sag the colder the spiral. The sag depends on the strength when hot, which itself depends on many factors—unsatisfactory ingredients in the alloy, temperature of pre-treatment,[7] grain size, etc. Low strength when hot is very disadvantageous in practice, yet, by Smithells' original method, such a sample runs with longest life, hence disagreement between test and experience is understandable.

TABLE I.
COMPARISON OF THE LIFE IN HOURS OF NICKEL-CHROMIUM DETERMINED BY DIFFERENT PROCEDURES.

Procedure (see Fig. 2)	*a*	*b*	*d*	*a*
Intermittency	2 mins. on, 2 mins. off.	15 mins. on 15 mins. off.	20 mins. on, 20 mins. off.	2 mins. on, 2 mins. off.
Initial temperature ..	1,050° C.	1,050° C.	1,050° C.	1,200° C.
Sample 1	650 (1)	210 (3)	1,120 (3)	47 (1)
" 2	450 (2)	122 (8)	580 (5)	22 (6)
" 3	420 (3)	260 (1)	580 (6)	42 (2)
" 4	280 (4)	157 (5)	1,310 (1)	30 (3)
" 5	250 (5)	256 (2)	1,250 (2)	30 (4)
" 6	175 (6)	124 (7)	540 (7) ..	22 (7)
" 7	120 (7)	202 (4)	640 (4)	23 (5)
" 8	100 (8)	126 (6)	300 (8)	18 (8)

TABLE II.
COMPARISON OF RESULTS GIVEN BY SCALING TESTS AT CONSTANT AND AT FALLING TEMPERATURE.

Sample No.	Life in Hours at 1,050° C. Constant Temperature.	Life in Hours at 1,050° C. Initial Temperature, Smithells' Method.
1	56, 57 } 57 (4)	80 to 145, mean 100 (5)
2	75, 76 } 76 (1)	430 " 615, " 450 (1)
3	45, 45 } 45 (5)	142 " 165 " 150 (3)
4	74, 62 } 68 (2)	91 " 290 " 150 (4)
5	60, 66 } 63 (3)	153 " 165 " 159 (2)

These difficulties are best overcome by keeping the temperature constant by means of a small variable resistance. This reduces the total time of test, and gives such good reproducibility of results that the test can serve as a standard for approval of material. In the most important of the subsequent experiments the temperature was maintained at 1,050° C. by this means, the spiral being allowed to hang freely as in Smithells' method (Fig. 2A). Table II. shows how this method compared with Smithells' method.

III.—Resistance Measurements during Scaling Tests.

In Smithells' method the resistance increases, due partly to the recrystallisation, this effect ceasing after a few hours; and partly to the reduction in cross-section on scaling, this effect continuing, the alteration in resistance thus giving a

7 W. Rohn, "Die Bestimmung der Kriechgrenze," *Festschrift zum 70, Geburtstag von Dr. W. Heraeus, Hanau*, 1930, p. 80. W. Rohn, "Die Kriechfestigkeit metallischer Werkstoffe bei erhöhten Temperaturen und ihre willkürliche Beeinflussung durch Warmevorbehandlung," *Z. f. Metallkunde*, vol. 24 (1932), pp. 127-31.

measure of the scaling. For certain purposes minimum alteration in resistance is desirable, and it has been proposed that the useful life should be regarded as the time in which the resistance increases by at most 10%, any time beyond this being disregarded.

To follow the alteration in resistance, an ammeter was connected in series, and a voltmeter in parallel with the spiral (Fig. 6) and read three times daily. In the first experiments the spiral was heated to 1,050° C., and the

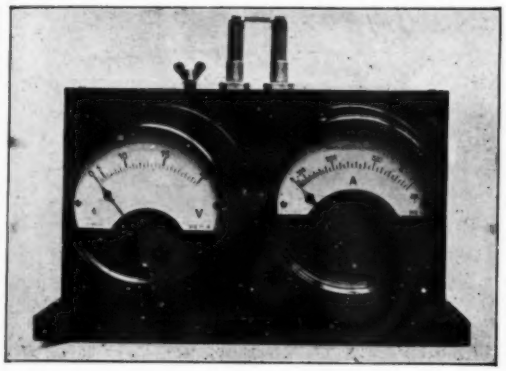


Fig. 6.—Apparatus for measuring electrical resistance during scaling tests.

resistance and fall in temperature followed, Fig. 7 showing the curves obtained. With sample *a* the resistance rises very rapidly, and the temperature falls quickly to about 1,030° C. A hot spot then develops, the resistance rises more rapidly, and the temperature falls still further. With sample *b* the resistance rises more slowly at first, but after 70 to 80 hours a hot spot develops and the rise is more rapid. The temperature curve is similar to that for *a*. Sample *c* remains practically unchanged for about 130 hours, when a hot spot develops in this alloy also.

To overcome errors due to falling temperature subsequent measurements were made at a constant temperature of 1,050° C. Fig. 8 shows the altered nature of the curves for the same kind of samples. The total lite is much shorter, and until a hot spot develops (see arrow) the increase in

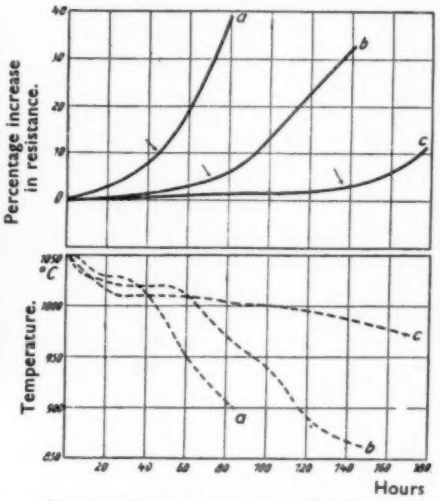


Fig. 7.—Rise in resistance and fall in temperature during test at constant voltage (initial temperature 1,050° C.)

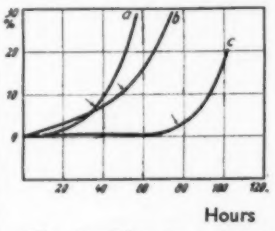


Fig. 8.—Rise in resistance during test at constant temperature (1,050° C.).

resistance per unit time is much greater than at falling temperature. The method of measuring resistance during scaling has proved highly satisfactory. Whereas previous methods merely gave the time to develop hot spots, or to fuse, a time influenced by various circumstances, with perhaps an idea of the fall in temperature, this method gives curves on which criticism can safely be based. The useful life is obviously the period during which the rise in resistance gives a straight line; the inclination to the horizontal is a measure of quality. Fig. 8 shows *c* to be two or three times as good as the others.

Bash and Harsh's rapid method has developed on similar lines, whilst the American Society for Testing Materials has issued standards for the life test of resistance alloys,[8] which correspond closely to that described here.

A satisfactory life test having been developed, the influence of various factors was investigated.

TABLE III.
INFLUENCE OF SMALL ADDITIONS ON THE HEAT RESISTANCE OF IRON AND NICKEL.

Sample Marked.	Composition.	Life in Hours at 1,050° C. Temperature Constant.		
		Individual Values.		Mean.
—	Electrolytic iron	1	1	1
V749	Fe + 2% Ni	1	1	1
V 748	Fe + 4% Ni	1	1	1
V 747	Fe + 6% Ni	1	1	1
V 759	Fe + 2% Cr	1½	1½	1½
V 758	Fe + 4% Cr	2	2	2
V 757	Fe + 6% Cr	2	1¾	2
V 756	Fe + 2% Co	1½	1½	1½
V 755	Fe + 4% Co	1½	1¾	1½
V 754	Fe + 6% Co	1¾	2	2
V 762	Fe + 2% Al	1½	2	2
V 761	Fe + 4% Al	5	4	4½
V 760	Fe + 6% Al	19	21	20
35/1428	Fe + 8·57% Al + 0·83% Mn + 0·16% Si	5	6	5½
V 753	Fe + 2% Si	8	9	8½
V 752	Fe + 4% Si	73	64	68½
39/972	Fe + 4% Si, 0·3 Ni	53½	54½	54
V 750	Fe + 4% Mn	1½	1¼	1½
	Fe + 12 Cr + 11 Ni + 1 Be	1	1½	1¼
33/493	Fe + 18 Cr + 8 Ni	11	11	11
V 789	Fe + 30 Cr + 30 Ni + 0·5 Mn + 0·5 Si	38	58	48
	Fe + 15 Cr + 61 Ni + 4 Mn + 0·5 Si	65	60	62½
V 189	Ni + 0·7% Mn	42		42
	Ni + 1% Mn	31	34	32½
	Ni + 4% Mn	17½	17½	17½
V 738	Ni + 2% Fe	22½	23½	23
V 740	Ni + 6% Fe	12½	12½	12½
V 741	Ni + 2% Cr	31½	32½	32
V 742	Ni + 4% Cr	12½	13½	13
V 743	Ni + 5% Cr	10	9	9½
	Ni + 11% Cr	21	19	20
V 506	Ni + 2% Al	38	40	39
V 507	Ni + 5% Al	36	38	37
V 493	Ni + 0·5% Si + 1% Mn	30	32	31
V 494	Ni + 1·5% Si + 1% Mn	69	64	66½
V 495	Ni + 2·5% Si + 1% Mn	60	83	71½
V 814	Ni + 3% Si + 0·3% Mn	75	65	70
V 496	Ni + 3·5% Si + 1% Mn	87	89	88
V 745	Ni + 6% Si + 0·3% Mn	25	28	26½
V 706	Ni + 1% Mn + 0·15% C	40	40½	40¼
P G	Ni + 2% Mn + 0·4% Fe + 0·1% Co + 0·1% Si + 0·1% C	42	40	41

IV.—Influence of Composition of Alloy on its Life.

The results of exploratory investigations of the effect of small additions of Mn, Si, Al, Cr, Co, and Ni to the basic constituents of the most important resistance alloys, to determine which most satisfactorily influenced the life, are given in Table III.

2–6% Mn, Co, or Cr, and up to 50% Ni only slightly lengthen the life of an iron wire. Al lengthens the life considerably, 6% raising it to 20 hours. Above 10% the effect is very marked, but the alloy is very brittle and difficult to draw. A less brittle alloy, with as long a life, contains 30% Cr and 5% Al. Silicon has a very marked effect, 4% raising the life to 68 hours. An alloy containing 11% Ni, 12% Cr, and 1% Be is no better than pure iron. A rustless steel containing 8% Ni and 18% Cr was better, but its life was only about one-seventh that of the alloy, 15% Cr, 65% Ni, 20% Fe. Higher chromium contents (up to 30%) further improved the life.

The life of nickel, pure or with 1% Mn, is 30–35 times that of iron, so that results here are higher. Fe, Mn, and, strangely enough, Cr up to 6%, have a bad effect. Even 10–12% Cr brings little improvement. Hence the previously widely used iron-free nickel alloy with 10–12% Cr cannot be considered very satisfactory. Up to 5% Al is without effect. Si has much the same effect as on iron, 3·5% giving a life of 88 hours. Figs. 9 and 10 show the results graphically as far as is possible.

8 "Tentative Standards for the Life Test of Resistance Alloys," *Proc. Amer. Soc. Test. Mat.*, vol. 32 (1932), No. 1, pp. 280-8.

The influence of Si is very significant.[9] Obviously, the silicon content should be as high as hardness and difficulty of working will permit. As Si is a powerful deoxidiser, this will also prevent the occurrence of chromic oxide inclusions. With too high a silicon content, Cr-Si compounds make their appearance after a long heating time.

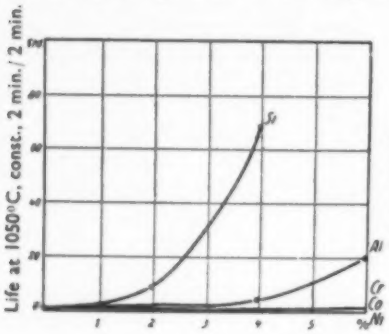


Fig. 9.—Influence of small additions of Si, Al, Cr, Co, and Ni on the life of thin iron wire at 1,050° C. (Diam. of wire 0·4 mm).

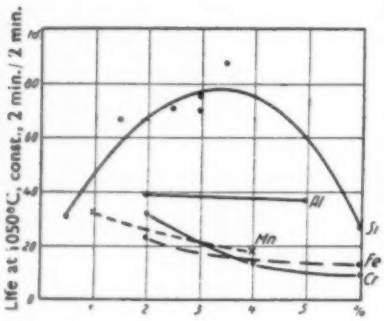


Fig. 10.—Influence of small editions of Si, Al, Cr, Fe, and Mn on the life of thin nickel wire at 1,050° C. (Diam. of wire 0·4 mm.)

Several commercial alloys were also tested (Table IV.). In Fig. 11 the results are plotted in relation to C, Cr, Si, and Mn content. As the Cr content of the iron-free alloys scarcely varies, nothing is learned of its effect. Si has a marked improving influence. Mn above 2% and C have a deleterious effect on these alloys. C has little effect on alloys containing iron, but more than 0·2% makes cold-working very difficult. Cr has a very marked effect, an increase from 11 to 20% more than doubling the life. Mn and Si have little effect. Consideration of the results gives no very definite indication of a particularly suitable composition.

Special attention was paid to molybdenum. In 1924 the Heraeus-Vacuumschmelze introduced an iron-containing alloy with 7% Mo, having 10–20% longer life than the Mo-free alloy, whilst 2% Mo was added to the iron-free alloy. Smithells[5] found up to 10% advantageous. Table V. shows the effect of increasing Mo content. Up to 8% the life increases; 10% causes no further increase, but considerable variation. Hermann[10] obtained no improvement with Mo. Alloy 22, Table IV., produced by special metallurgical treatment, proves that Mo-free alloys may actually give better results.

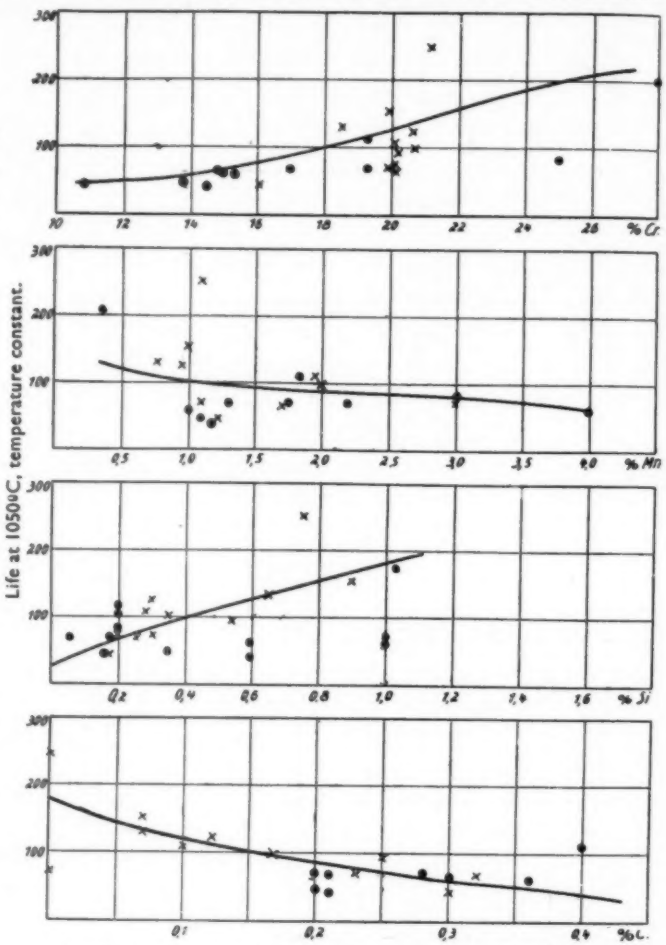


Fig. 11.—Influence of Cr, Mn, Si, and C on the life of nickel-chromium of the 80/20 class (crosses), and the 65/15/25 class (dots).

TABLE IV.
COMPOSITION AND LIFE OF VARIOUS NICKEL-CHROMIUM ALLOYS.

—	Ni.	Cr.	Fe.	Mo.	Mn.	Si.	C.	Al.	Other Elements.	Life in Hrs. at 1050° C. Temp. C'stant.
1	60·4	15·0	20·0	0·0	4·0	0·6	0·04	—	—	62·5
2	61·6	14·9	19·9	0·0	1·31	1·0	0·21	0·1	0·6 Co, Cu Sp.	68·0
3	63·4	10·8	24·2	0·0	1·20	0·6	—	0·2	—	42·0
4	60·75	17·0	19·8	0·0	2·20	0·06	0·28	Sp.	0·2 Co. 0·1 Cu	70·0
5	64·7	14·49	19·67	0·0	0·12	0·17	0·20	Sp.	0·0 Co. 0·2 Cu	41·0
6	50·0	33·0	13·0	2·0	2·0	0·20	0·04	—	—	105·0
7	60·0	25·0	10·0	2·0	3·0	0·20	0·04	—	—	82·5
8	68·75	19·32	9·37	0·0	1·76	0·18	0·20	—	0·25 Cu	70·0
9	75·5	19·50	2·76	0·0	1·0	0·90	0·07	Sp.	0·20 Co. 0·0 Cu	155·0
10	69·71	19·3	7·70	0·0	1·85	0·20	0·40	Sp.	0·7 Cu	112·5
11	77·4	20·6	0·45	0·0	0·95	0·30	0·12	Sp.	0·2 Cu	123·0
12	78·4	18·5	1·35	0·0	0·78	0·65	0·07	—	0·0 Co. 0·04 Cu	130·0
13	77·1	20·2	0·30	0·0	1·96	0·28	0·10	0·1	0·3 Co. Cu Sp.	107·5
14	76·2	20·7	0·32	0·0	2·00	0·35	0·17	Sp.	0·2 Co. Cu Sp.	100·0
15	74·7	20·0	1·50	2·0	3·0	0·20	0·03	—	Sp. Co. Cu Sp.	72·5
16	78·4	20·22	0·49	0·0	0·0	0·54	0·25	Sp.	0·0 Co, 0·22 Cu	93·0
17	77·25	19·9	0·72	0·0	1·10	0·30	0·23	0·1	0·0 Co, 0·2 Cu	70·0
18	82·2	15·3	0·0	0·0	1·00	1·00	0·03	0·5	—	57·5
19	83·4	13·8	0·77	0·0	1·10	0·35	0·20	0·1	0·0 Co, 0·37 Cu	47·5
20	80·75	16·05	0·96	0·0	1·23	0·17	0·30	0·1	—	42·0
21	76·70	20·1	0·40	0·0	1·71	0·25	0·32	—	0·1 Co. 0·0 Cu	66·0
22	76·80	21·1	0·20	0·0	1·10	0·75	0·02	—	—	250·0

TABLE V.
LIFE OF IRON-FREE NICKEL-CHROMIUM ALLOYS WITH DIFFERENT AMOUNTS OF MOLYBDENUM.

Composition (Rest Nickel).					Life (1,050° C. Constant).	
Cr.	Mo.	Mn.	Si.	Al.	Individual Results.	Mean.
20	2	3	—	—	68, 72, 70	70
20	6	3	0·3	0·8	87, 85, 82, 78, 79	82
20	8	3	0·3	0·8	107, 148, 120	115
20	10	3	0·02	0·8	135, 121, 128	128
20	10	3	0·20	0·8	81	81
20	10	0·2	—	0·8	109	109

TABLE VI.
INFLUENCE OF FE ON THE LIFE OF IRON-FREE NICKEL-CHROMIUM.

Charge No.	Analysis.			Life in Hours at 1,050° C. Temperature Constant.		
	Ni	Cr.	Fe.	Individual Results.		Mean.
26/930	74·2	20·2	0·47	70·5	71·5	71
26/929	73·8	20·1	0·86	66	72	69
26/925	73·1	19·84	1·80	71	72	71·5
26/1100	73·0	19·82	2·20	67	62	64·5
26/1101	73·0	19·82	2·20	77	78	77·5

As shown in Table VI., up to 2·2% Fe has little effect on 80/20 Ni-Cr alloys.

9 J. A. Mathews, "Recent Developments in Corrosion-Resistant and Heat-Resistant Steels," *Ind. Eng. Chem.*, vol. 21 (1929), p. 1,158. N. B. Pilling and R. Worthington, "The Effect of Temperature on Some Properties of Iron-Chromium-Nickel Alloys," *Symp. Effect of Temp. on the Properties of Metals*, Chicago, 1931.

10 W. Hermann, "Warmefeste Speziallegierungen (Ni-Cr-Fe-Gruppe)," *Feuerungstechnik*, vol. 20 (1932), pp. 114-6; *S. a. Metallurgist* (1932), pp. 76-9.

V.—Influence of Surface Treatment on the Life of Nickel-Chromium Alloys.

A poor quality Fe-Cr-Ni alloy, 15% Cr, 50% Ni, was plated with a few hundredths of a mm. of chromium or copper and the life determined. Table VII. shows that plating is practically without effect. Coppering and subsequent chromium plating gave no better result. Efforts were also made to cement Ni-Cr wires with C, Al, and Si; the coatings were very irregular and started scaling off after 2 hours. Hence no improvement can be obtained in this way.

TABLE VII.
INFLUENCE OF ELECTROPLATING.

Treatment.	State.	Life at 1,050° C. Individual Results.	Temperature Constant Mean.
Normal	Annealed	55½, 54	55
Cr-plated	Hard	52½	52½
Cr-plated	Annealed	61, 63	62
Cu-plated	Annealed	54, 56	55

VI.—Influence of Furnace Atmosphere on the Life of Nickel-Chromium Alloys.

Spirals of the two main alloys and of one containing molybdenum were tested in atmospheres of nitrogen, oxygen, carbon monoxide, and dioxide at 1,050° C. (Table VIII.). The two latter somewhat lengthen the life, owing to reduced oxidation. At 1,200° C., however, they have a a very bad effect, carbon going into solid solution but

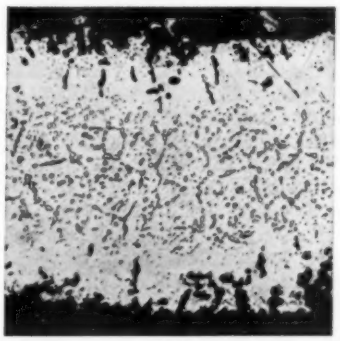


Fig. 12.—Carbide segregation in nickel-chromium annealed in CO.

separating at the crystal boundaries on cooling. Fig. 12 shows such carbide segregation, which causes sponginess before going back into solution, owing to its very different coefficient of expansion. The interior of the wire is thus exposed to oxidation, and the illustration shows how far this proceeds at the grain boundaries where the carbide has been.

TABLE VIII.
INFLUENCE OF VARIOUS GASES ON THE LIFE OF NICKEL-CHROMIUM ALLOYS AT 1,050° C.

Sample No.	Class of Alloy.	In Air (Normal)	Life in Hours* (2 mins. on, 2 mins. off).			
			In CO_2.	In CO.	In N_2.	In O_2.
I	80 Ni, 20 Cr.....	80	97	89	89	69
II	65 Ni, 18 Cr, 15 Fe	75	94	68	89	65
III	60 Ni, 15 Cr, 7 Mo, 18 Fe	82	104	87	102	64

* Means of at least three tests.

VII.—Influence of Diameter of Wire on the Life at 1,050° C. Constant Temperature.

The life of the finer wires is proportional to the diameter, but with greater thicknesses it increases only slightly, and above 0·6 mm. is practically independent of the diameter with the alloy containing iron (Fig. 13). Wires 5–6 mm. diameter are preferred in industrial furnaces, local destruction of a film 0·1 mm. thick meaning a loss of only 6% in cross-section, as against 20% on a 2 mm. wire. The resulting overheating in the latter would in time lead to fracture.

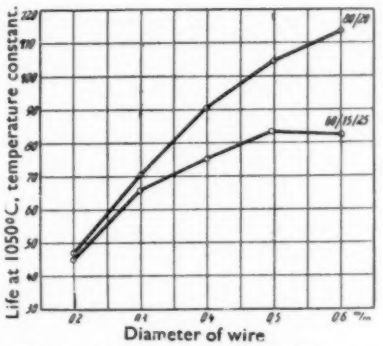


Fig. 13.—Influence of diameter of wire on the life at 1,050° C. constant temperature.

VIII.—Influence of Annealing Temperature.

Wires 0·25 mm. diameter were tested at 900° C., the life being 13 to 15 times that at 1,050° C. (Table IX.). Hence the use of sufficient quantity of resistance wire to permit a reduction of 20–30° in the temperature of the heating elements of an electric furnace, whilst maintaining that of the material being annealed, is of great importance to the life of the furnace. See also Fig. 3.

TABLE IX.
LIFE OF NICKEL-CHROMIUM AT 900° C. DETERMINED ON WIRE 0·25 MM. DIAMETER.

Class of Alloy.	Life in Hours.		Life at 1,050° C. Temp. Constant (Calculated from 0·4 to 0·25 mm. Diameter).	Ratio. 900° : 1,050°
	Individual Results.	Mean.		
65 Ni, 15 Cr, 20 Fe	536 522	529	35	15·0
80 Ni, 20 Cr.....	633 638	636	44	14·5
60 Ni, 15 Cr, 7 Mo, 18 Fe	645 655	650	50	13·0

IX.—Brittleness of the Experimental Spirals after Use.

Heating elements are often required to withstand mechanical stresses during use without fracture. Spirals were therefore tested by straightening and re-coiling after each two-hour heating period, the amount of oxide scaling off determining the quality. In another series toughness was determined by heating at 1,050° C. for 50 hours, then coiling and uncoiling till fracture occurred. Table X.

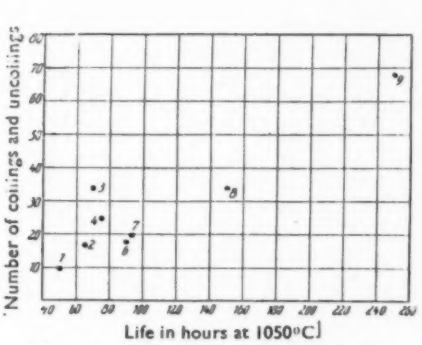


Fig. 14.—Relation between life and brittleness of nickel-chromium wires.

TABLE X.
BRITTLENESS OF NICKEL-CHROMIUM TEST SPIRALS AFTER 50 HOURS' HEATING AT 1,050° C.

Sample No.	Life at 1,050° C. Temperature Constant.	No. of Coilings and Uncoilings.	Bend Test.
1	50	10	16
2	65	17	12
3	70	34	17
4	75	25	15
5	75	22	16
6	90	18	11
7	93	20	10
8	150	34	14
9	250	68	24

shows these results and those of bend tests (radius of bend = 5 times diameter of wire).

The results are reproduced in Fig. 14, and show a certain connection between the life and the brittleness after heating. In general, the longer the life the less sensitive the spiral to flexure, due to the smaller grain size of the better nickel-chromium alloys, as will be shown later. The bend test shows little relation to the life. Evaluation of the wires based on scaling[4] showed a fairly close agreement with the new method, and evidently gives more reliable results than would at first appear likely.

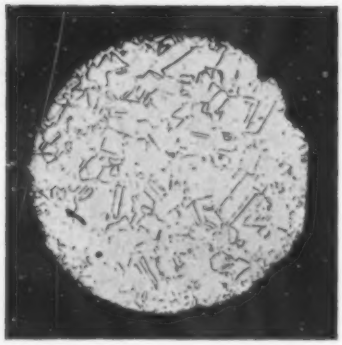


Fig. 15.—Nickel-chromium wire with medium grain. Before use. Etched with aqua regia × 100.

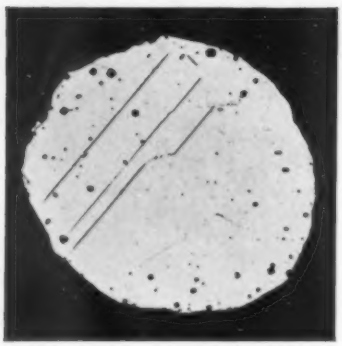


Fig. 16.—Same wire as in Fig. 15, but with coarse grain. Before use. Etched with aqua regia × 100.

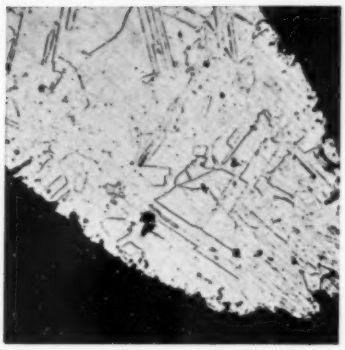


Fig. 17.—Same wire as in Fig. 15, after 60 hours' heating at 1,050° C. *(Oblique section). Etched with aqua regia* × 100.

X.—Influence of Grain Size on the Life of Nickel-Chromium Alloys.

Figs. 15 to 18 show the influence of grain size. Prolonged discontinuous heating at 1,200° C., with occasional slight working, converts the medium grain (Fig. 15) into the coarse grain (Fig. 16), the life at 1,050° C. falling from 60 to 35 hours. Figs. 17 and 18 show the wires after the test. Attack takes place at the crystal boundaries and proceeds further with the coarse than with the fine grain.

XI.—Influence of Intermittency on the Life of Nickel-Chromium Alloys.

Alternate cooling and heating makes the oxide scale off. As a thin oxide film prevents further oxidation, frequent switching on and off must shorten the life considerably. The influence of intermittency can be determined with the apparatus already described, as the on and off time can be varied. Table XI. shows results with intermittencies of 2 and 20 mins., the life being the total time up to burning through, whilst the burning period is the time the wire is actually at 1,050° C. The effect of frequent switching is very marked.

TABLE XI.
INFLUENCE OF INTERMITTENCY ON THE LIFE. TESTS CARRIED OUT AT A CONSTANT TEMPERATURE OF 1,050° C.

Mark.	Composition, % by Weight.	Life in Hours.			Burning Period in Hrs.		
		2 mins.	20 mins.	Unbroken.	2 mins.	20 mins.	Unbroken.
261,093	61 Ni, 18·5 Cr, 16·5 Fe, 3 Mn, 0·6 Si	72	266	202	36	133	202
15,274	61 Ni, 15 Cr, 7 Mo, 15 Fe, 1·4 Mn, 0·6 Si	82	281	280	41	140	280
161,317	77·4 Ni, 20·5 Cr, 1 Mn, 0·3 Si	125	474	286	62·5	237	286
5,888	76·8 Ni, 21·0 Cr, 1·2 Mn, 0·8 Si	286	926	630	143	463	630

The length of the "off" period also has its effect. 2 mins. on and 6 off gives a burning period 20–30% shorter than 2 on and 2 off, although in both cases the difference from room temperature 10 secs. after switching off is less than 10°. Spontaneous scaling per unit time is still increasing after the first 10 to 20 mins. after switching off, and ends only after 10 to 20 hours.

XII.—Influence of Method of Production.

The method of production and metallurgical treatment have a very definite influence.

Previously Ni-Cr and Ni-Cr-Fe alloys were produced in crucibles or small electric-arc furnaces, and took up 0·2 to 0·4% C. This reduced the life at temperatures above 1,050° C., and also caused trouble during fabrication. In modern high-frequency furnaces uptake of C is impossible, but considerable risk of oxygen absorption exists. This results in chromic oxide segregation at the crystal boundaries, which further endangers the most susceptible point. Fig. 19 shows Cr_2O_3 inclusions in a strongly oxidised Ni-Cr alloy. The inclusions, even when not so marked, can be recognised by their characteristic shape.

Uptake of C, O, and N can be prevented in two ways. Smithells[12] strongly advocates melting in an atmosphere of hydrogen, whilst the Heraeus-Vacuumschmelze has for years melted and cast in vacuum.

When Cr and Ni or Cr, Ni and Fe are melted in an atmosphere of pure hydrogen, the chromium oxide first formed is gradually reduced, the melt becoming clear. Hydrogen is taken up, but is given off on solidification, rising or spurting occurring. Sound ingots are obtained by replacing the hydrogen by nitrogen towards the end.

The same materials melted in vacuum form only a little slag, from oxide introduced with the material. Addition of Mn or Si produces a clear melt and sound, dense ingots. Characteristic differences are shown by wires produced by these three methods :—

Life at 1,050° C. of Ni-Cr melted in open high-frequency furnace :
(*a*) Solidified in crucible ..... 52 hours.
(*b*) Cast in copper chills ..... 80 ,,
Life of Ni-Cr melted in hydrogen :
(*a*) Solidified in crucible ..... 90 hours.
(*b*) Cast in copper chills ..... 100 ,,
Life of Ni-Cr melted in vacuum :
Cast in copper chills ..... 112 hours.
All 80-20 Ni-Cr, without additions.

The influence of various additions when melting in hydrogen was investigated. Deoxidisers—*e.g.*, Si, Mn, and

11 W. F. Randall, "Electric Resistance Alloys for High Temperature Service," *Electric Review*, vol. 35 (1932); *Metallurgia*, vol. 6 (1932), pp. 125-7.
12 C. J. Smithells, S. V. Williams, and E. J. Grimwood, "Melting Nickel-Chromium Alloys in Hydrogen," *J. Inst. of Metals*, vol. 46 (1931), pp. 443-456.

Fig. 18.—Same wire as in Fig. 16 after 35 hours' heating at 1,050° C. *(Oblique section). Etched with aqua regia* × 100.

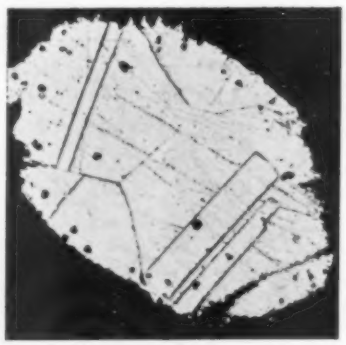
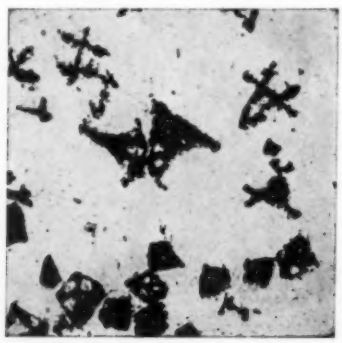


Fig. 19.—Cr_2O_3 inclusions in over-oxidised nickel-chromium. Etched in aqua regia × 100.



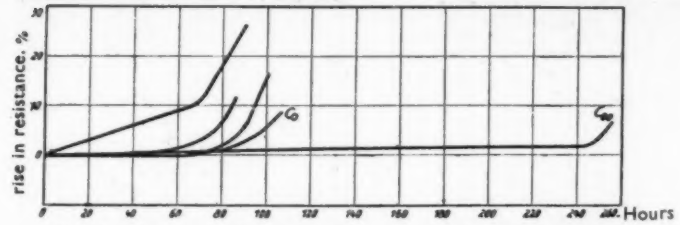


Fig. 20.—Rise in resistance curves of iron-free nickel-chromium alloys at 1,050° C.

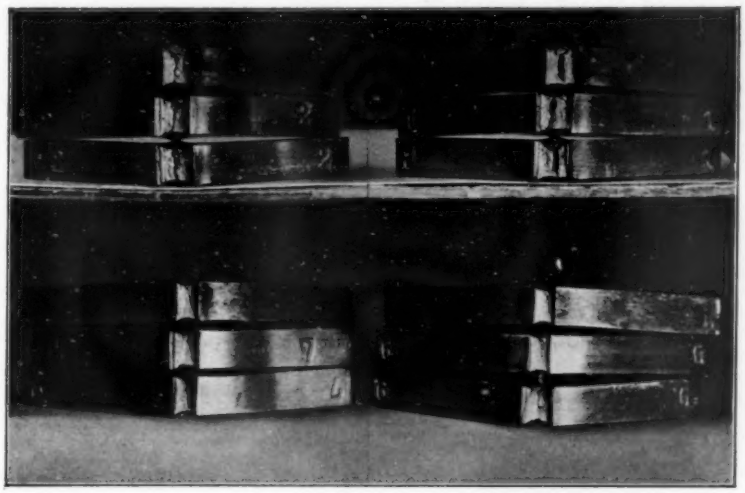


Fig. 23.—Notch impact tests on open-furnace nickel-chromium (upper series) and vacuum-furnace nickel-chromium (lower series). Alloy I. Alloy II.

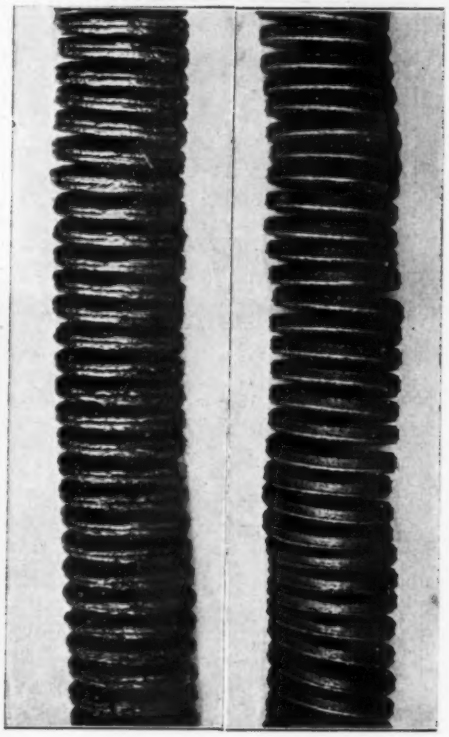


Fig. 21.—C_0-spiral (left) and C_{00} spiral (right) after 200 hours' service at 1,200° C.

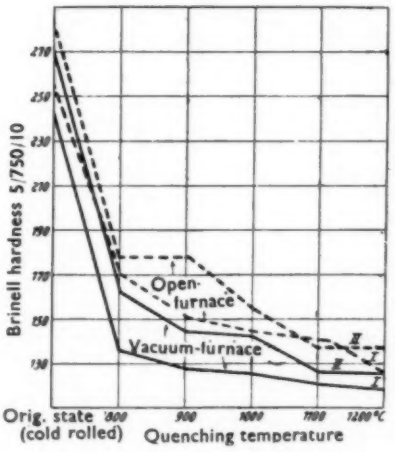


Fig. 22.—Brinell hardness of open-furnace and vacuum furnace nickel-chromium.

I. 60·4 % *Ni*, 15% *Cr*, 20% *Fe*, 4% *Mn*, 0·6% *Si*.

II. 58·9 % *Ni*, 15% *Cr*, 18% *Fe*, 4% *Mn*, 1·0% *Si*, 1·5% *Mo*, 0·8% *Co*, 0·3% *W*, 0·5% *Cu*.

Al—have more effect than the hydrogen, which is of marked advantage only when no deoxidiser is to be used. Moreover, replacement of hydrogen by nitrogen before casting may produce Cr-nitrides, part of the advantage of using hydrogen being lost.

In the vacuum furnace the alloy may remain molten for long periods without uptake of impurities; in the open furnace excess deoxidiser is needed to prevent oxidation when pouring. Iron-free alloys, C_0 and C_{00}, manufactured by Heraeus-Vacuumschmelze, were compared with similar alloys of home and foreign manufacture. The resistance curves (Fig. 20) show the marked superiority of C_{00}, which may be used at temperatures of about 1,200° C. Fig. 21 shows spirals of C_0 and C_{00} after 200 hours' use alongside each other at 1,200° C.; C_0 is in some places almost completely destroyed, and is covered with a scaly slag; C_{00} is still perfect. Vacuum-melted Ni-Cr alloys have also the advantage of lower Brinell hardness than the ordinary alloys when annealed at 800° to 1,200° C. (Fig. 22).

Fig. 24.—Microstructure of vacuum-furnace Ni-Cr before use. Etched with aqua regia ×200.

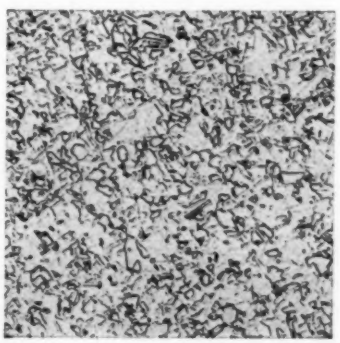


Fig. 25.—Destruction of an Ni-Cr wire by oxidation along the crystal boundaries. (Longitudinal section). Etched with aqua regia × 100.

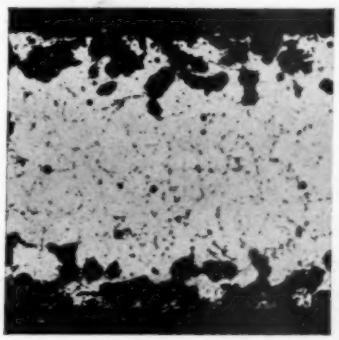
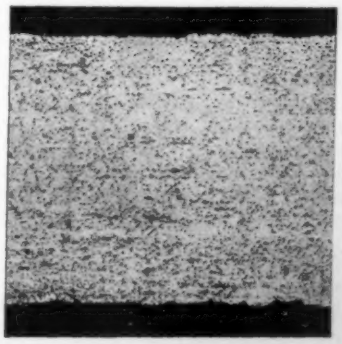


Fig. 26.—Longitudinal section through a fine-grained Ni-Cr wire before use. Etched with aqua regia × 100.



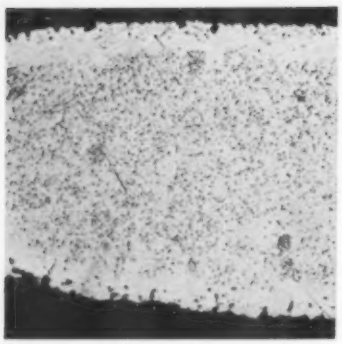


Fig. 27.—Longitudinal section (slightly oblique) through the same wire as in Fig. 26, after 250 hours' heating at 1,050° C. Etched with aqua regia × 100.

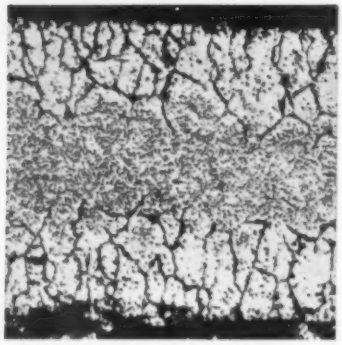


Fig. 28.—Heavy intercrystalline oxidation of an Ni-Cr wire. Etched with aqua regia × 100.

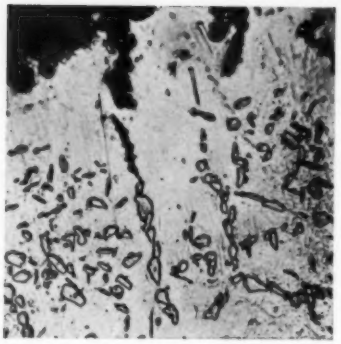


Fig. 29.—Segregation of Fe-Cr-Ni compounds in Ni-Cr, containing 33% Cr, 50% Ni, 13% Fe, 2 % Mn, and 2% Mo. Etched with aqua regia × 500.

The difference is most marked, however, in the notch impact test (Fig. 23 ; 10 mkg. blow). Chemically, the alloys are the same. The notch impact samples of the open-furnace alloy exhibit cracks in every case at the base of the notch, the other samples of the vacuum-melted alloy have merely deformed by flowing. This advantage is of importance in furnace parts under stress at high temperatures, and arises from freedom of grain boundaries from non-metallic inclusions.

XIII.—Metallographic Investigations.

The Ni-Cr alloys are austenitic, the section of an unused wire showing a homogeneous mass of crystallites (Fig. 24). After the scaling test, there is a characteristic change. Preferential oxidation occurs at the crystal boundaries, a spongy structure penetrating from the surface. Fig. 25 shows this effect on a very bad sample, and also shows how segregation at the grain boundaries during use assists oxide attack. The life was 70 hours. Figs. 26 and 27 show a fine-grained vacuum-melted Ni-Cr alloy before and after a 250 hours' test. The wire is practically unoxidised.

Fine grain alone is not sufficient, as Fig. 28 shows. After only 81 hours' life, the sound cross-section is but 10% of the original, 1% of an element forming a chromium compound segregating at the grain boundaries having accelerated the oxidation.

Ni-Cr-Fe alloys before use consist of a homogeneous solid solution. In service a compound belonging to the heterogeneous range separates at the crystal boundaries and in part within the crystals. Separation increases with the Cr content. Prolonged heating appears to displace the phase limit shown in Fig. 1, originally homogeneous alloys becoming heterogeneous. Impurities also have this effect. Fig. 29 shows such segregation in the alloy 33% Cr, 50% Ni, 13% Fe, 2% Mn, 2% Mo. Oxidation has followed the segregations. Loss of toughness on prolonged heating is probably due to such segregation.

Consolidated Specifications for Carbon-Steel Castings.

Consolidated specifications for carbon-steel castings for industrial, railroad, and marine uses were recently approved for publication as tentative by the American Society for Testing Materials on the recommendation of its Committee A1 on steel. Certain confusion had arisen due to the fact that the present specifications for carbon-steel castings had varying requirements for the same grades of steel. It was realised that the interest of producers and consumers would best be served if major requirements for identical grades were made uniform with exceptions noted as justified for castings for certain special purposes.

The special committee appointed to investigate the whole matter, after careful study, found that its objectives could best be obtained by drafting a consolidated specification which could ultimately supersede the present specifications, generally called the miscellaneous and railroad steel castings, respectively. The committee has put in the body of the new specifications all general clauses that apply to general railroad and marine applications, and in supplements requirements applying exclusively to marine and railroad castings. The committee urged the approval of the proposed specifications as representing the most satisfactory present basis for harmonising differences of opinion held by informed persons regarding proper purchase requirements for the material.

The specifications apply to carbon-steel castings for miscellaneous and jobbing purposes, for locomotive and car equipment, and for ship construction. Two classes and five grades are provided for. The steel is to be made by one or more of the following processes: Open-hearth, electric-furnace, converter, or crucible. Detailed requirements for heat treatment are included. The maximum carbon content of class A castings is put at 0·45%, with manganese 0·50—1·00 ; silicon, 0·20—0·75 ; maximum phosphorus, 0·05 ; maximum sulphur, 0·06. No carbon content is specified for class B castings, inasmuch as physical requirements are given, and the requirements for the other elements are the same as in the class A castings. The tensile requirements for class B castings are as follows :—

	Grade of Class B Casting.			
	Regular.	Special No. 2.	Special No. 3.	Special No. 4.
Tensile strength, lb. per sq. in.	70,000	60,000	60,000	80,000
Yield point, lb. per sq. in.	38,000	30,000	30,000	43,000
Elongation in 2 in. per cent. ..	24	22	26	17
Reduction of area, per cent. ..	36	30	38	25

A supplement for marine castings provides that all castings shall be of the regular grade class B. Castings listed include stern frame, rudder, steering quadrant, propeller shaft bracket, tiller, etc. Requirements are included for bend and percussion tests. A supplement for railroad castings requires that tension tests be made from bars attached to each locomotive frame, locomotive cylinder, wheel centre, etc. Copies of the specifications can be obtained from A.S.T.M. Headquarters, 1,315, Spruce Street, Philadelphia, Pa.

Reviews of Current Literature.

Heræus Vacuum Schnielze, 1923-1933.

Although this book has been published primarily to celebrate the anniversary of the foundation of a German company, it constitutes an important contribution to technical literature. During six years prior to the foundation of this company the process of melting *in vacuo* was investigated in one of the departments of the W. C. Heræus G.m.b.H., and was developed to a practical stage as a metallurgical process, and this book really gives a brief report of the work which was carried out during 16 years, and describes some improvements made in the various equipments and laboratories. Dr. W. Rohn, who has a world-wide reputation, is the author of this historical account; he points out that initially the refinement obtained by melting *in vacuo* was directed to the manufacture of thermo-couples, since the high purity of the alloys which was obtained by the process could be reproduced regularly with accuracy of composition. In this way it was found possible to substitute other alloys for platinum and its alloys for this purpose. Gradually the process developed on a larger scale and a wider application found for the refined alloys it produced.

The book contains several articles of more than ordinary interest, many of which have been prepared as a result of investigations carried out in the laboratories of the company; some of these have been designed to show the advantages of alloys melted *in vacuo*, but they form valuable contributions to metallurgical development. Some indication of the scope of these articles is obtained from the following subjects, which are included :—Pure iron carbonyl as a highly permeable, magnetic industrial material; an electrode material for spark spectroscopic purposes; relaxation of elastic stresses, compared with the relaxation of other properties; the transversal variation in the ferromagnetic resistance of pure nickel; the gaseous reduction of chromium oxide to chromium; production of carbon-free chromium alloys from carbon-containing ferrochrome; creep limit and creep speed; resistance alloys for temperatures up to 1,300° C.; the influence of the strip thickness, the annealing atmosphere, and the simultaneously-annealed inter-insulation on the original and maximum permeability of coiled strip cores made of nickel-iron alloys; vacuum melted beryllium alloys; the resistance of acid-resisting and age-hardening nickel-chromium alloys to intercrystalline corrosion; nickel-chromium alloys and their life test; sulphur resisting alloys; the development of a technical casting precedure for beryllium-copper alloys; melting point diagrams of highly refractory oxides containing lime; induction furnace for alternating current of grid frequency; rolling mills with rolls of minimum diameter; coiling machine with a constant tensioning device; multiple wire-drawing machines with individual motors; alloys for springs with low-temperature coefficients for the modulus of elasticity; the influence of corrosion on the fatigue strength of nickel-chromium alloys; and others. One of the articles, in which is discussed various methods of testing nickel-chromium resistance alloys, as well as a new life test method, is published in this issue, in an abridged form, by the courtesy and collaboration of Dr. W. Rohn and his colleague, Dr. W. Hessenbruch. This book is admirably prepared and produced, and is a credit to the company and to the editor.

Manual on Presentation of Data.

The promotion of knowledge of engineering materials and the standardisation of specifications, and the methods of testing, involve at every turn the utilisation of data. Such data form an important source for the development of new knowledge, and in selecting standards of quality and methods of testing that are adequate, satisfactory, and economic from the standpoints of the producer and the consumer. It is, therefore, necessary that data should be presented in a form conducive to its successful application, and this manual deals specifically with presentation. In addition, however, it discusses briefly some of the reasons why the problem of the presentation of data cannot be isolated and treated independently of the problems of collection and interpretation.

This manual has been prepared by a special committee of engineers, selected by the American Society for Testing Materials, who are at the same time statistical experts. This committee consisted of Messrs. H. F. Dodge, chairman, member of Technical Staff, Bell Telephone Laboratories Inc.; J. T. MacKenzie, Chief Chemist, American Cast Iron Pipe Co.; R. T. Webster, Quality Standards Branch, Western Electric Co.; and A. E. R. Westman, Director of Chemical Research, Ontario Research Foundation. Its object was to correlate and make available in convenient form some of the principles of efficient presentation of data. The application of statistical methods is discussed under two main headings: (1) To the problem of condensing information contained in a set of observations; and (2) to the problem of presenting the essential information in a concise form more readily interpretable than the unorganised mass of original data. Attention is directed particularly to quantitative information on measurable characteristics of materials and manufactured products.

In addition to pointing out the important measures and values which are especially useful for summarising information contained in a set of observations, the committee has given methods of computation. In a particular instance the functions of the data which should be presented depend upon what uses are to be made of them, and, accordingly, there is a section devoted to essential information. Critical comments on various methods used in presenting data are also given, a discussion of what relevant information should accompany the data and the committee's recommendations for data presentation.

In this manual attention is restricted to one of several types of data such as are gathered by individuals or committees and presented to the American Society for Testing Materials. The discussion is directed primarily upon physical constants and frequency distributions, emphasising particularly the nature of the frequency distributions for physical properties of materials and for errors of measurement. The whole field of interpretation and presentation of data is becoming an increasingly important one, and this manual is a valuable contribution to the problems involved. It comprises 45 pages and can be obtained from the American Society for Testing Materials, 1,315, Spruce Street, Philadelphia, Pa., at 50 cents per copy.

Journal of the Institute of Metals, Vols. L. and LI.

Volume L. of this Journal is the second to be devoted entirely to metallurgical abstracts as distinct from original papers. It is a weighty book of 962 pages, of which the index covers no fewer than 177 pages. It contains concise summaries of a metallurgical character, primarily concerned with non-ferrous metals, that have recently appeared in the world's technical press. There are thousands of such abstracts and the book should prove invaluable to all who have to do with metals.

The latest volume, Vol. LI., constitutes a record of the Institute's recent annual meeting, at which 13 important metallurgical communications were presented and discussed. Each paper is now reproduced together with the relative discussions. In addition, it contains the annual May lecture on "The Phenomena of Quenching and Tempering in Alloys," which was delivered by Professor Albert Portevin.

Both are edited by G. Shaw Scott, M.Sc., F.C.I.S., the Institute of Metals, 36, Victoria Street, London, S.W. 1. Price for Vol. L., £4, inclusive of two "Proceedings" Vols.; and for Vol. LI., 31s. 6d.

Corrosion of Iron and Steel.

THE reprinted report of A.S.T.M. Committee A-5 on the above subject includes much data on the extensive series of tests this group has had under way, some of them since 1916. It includes a detailed record of the failures in the Annapolis atmospheric corrosion tests comparing copper-bearing with non-copper-bearing materials. The 259 sheets of No. 16 gauge material and 227 sheets of No. 22 gauge have been inspected twice a year since the sheets were exposed in 1916. Several failures of various materials have occurred. In an appended report the sub-committee on total immersion tests gives complete data on failures of 22-gauge and 16-gauge copper-bearing and non-copper-bearing sheets exposed for the past five years in sea water at Key West, Fla., and Portsmouth, New Hampshire. Each of the 150 22-gauge sheets at Key West and at Portsmouth have failed, and there have been many failures in the 16-gauge sheets at Key West. A record of these failures is given in detail.

The sub-group working on field tests of metallic coatings presents extensive tabulations and graphs giving the results of the latest inspections of galvanised and uncoated sheets. Results of inspections on coated hardware, structural shapes, tubular goods, etc., are given in a series of tables. The report also includes the revised standard methods of determining weight of coating on zinc-coated iron or steel articles, and reports of the sub-group on specifications for metallic-coated products and on embrittlement investigations are also given.

Copies of this report can be obtained from the A.S.T.M., 1,315, Spruce Street, Philadelphia, at 50 cents each. 36 pp.

Standard Methods of Analysis.

IT is rather unusual for a large organisation to publish methods that have contributed to its success, and this volume may be taken as a welcome sign of the times. It is an indication that users of materials are becoming more technically minded, and are likely to appreciate the compliment the opportunity of having tried methods of analysis at their disposal. The publishers comprise a large group of firms manufacturing iron and steel in many forms; the group possesses many laboratories in different parts of the country, and these are continually engaged in tests and analyses of every grade of iron, steel, and ferro-alloys, either as finished or semi-finished products, or as raw materials.

It became apparent that it would be convenient to standardise the procedure adopted by these various laboratories, and to this end a committee of chemists and metallurgists was appointed to scrutinise carefully the various methods available and to pronounce upon those which they considered best for adoption throughout the whole group of companies. The selected standard methods determined by that committee are published in this volume. No "short" or approximate methods are included, as it was considered that these, however useful, do not fall within the scope of the word "standard."

These methods of analysis are already in daily use as standard practice by a large number of metallurgical chemists now employed in the manufacture of the whole of the output of this large group of firms, which amounts to about one-sixth of the total production of steel and a large proportion of the basic and hematite pig irons made in the United Kingdom.

We believe these standards will find appreciation amongst a wider public by the iron and steel manufacturing and consuming industries in particular. The book is well produced, and is bound with interleaving of feint-ruled paper for additional notes by the reader and user. All metallurgists will find it of special interest and value. 36 pp. bound in black and gold. 9 in. × 6 in. Published by the United Steel Companies, Ltd., 17, Westbourne Road, Sheffield. Price 4s. 6d.

Minerals Year Book.

THIS is the first issue of a year book, which takes the place of "Mineral Resources of the United States," which has been issued annually for over half a century, and presents a statistical and economic résumé of conditions in the mineral industries that is of practical value in the task of recovery in these basic industries that employ more than 1,700,000 men, and furnish over half the tonnage handled by railroads.

A review of the United States mineral industries reveals a recession during the last three years unprecedented in extent and duration. This condition was due principally to the inability of markets to absorb the output of the mills and factories that normally provide an outlet for the products of mines and smelters. The mineral production had a total value of about 29 billion dollars from 1925 to 1929, a yearly average of approximately 5.7 billion dollars. In 1930 it was 4.8 billion dollars; in 1931 the total had fallen to 3.2 billion dollars. For 1932 our mineral production was worth about 2.4 billion dollars, a decrease of around 57% from the average value for the five-year period. Of the three main groups of minerals the general recession has affected metals and mineral fuels least.

A few comparisons will indicate the low levels to which quantity production of some of these commodities fell in 1932. Pig-iron output was the lowest since 1896. Although the copper yield exceeded that of 1921, a post-war depression year, it only slightly topped the 1898 figure. The output of lead was the lowest since 1899, and of zinc the smallest since 1905, excluding 1921. Silver yield was the least since 1875. Bituminous coal and anthracite production approximated the levels of 1905 and 1890, respectively.

While prices of many mineral commodites have fallen below cost of production, it is obvious that such a condition cannot continue indefinitely. Three years of steadily declining consumption caused accumulation of excessive stocks, while recurring distress sales drove prices downward, a trend that has recently shown progressive abatement. With drastic curtailment of production the increase of stocks has generally ceased, and surplus stocks are more strongly held than in the recent past.

Advancing consumption has persisted through a century, indicating a deep-lying tendency to grow that cannot be repressed indefinitely. The steady rise of living standards was made possible chiefly through increased utilisation of minerals and metals. From 1860 to 1929 our population was multiplied by four, the value of agricultural production by six, that of manufactures by 22, and that of mining output by 60. Our living standards will advance further; the present low level of mineral consumption should not continue long.

This first volume bears the two dates 1932-33, in order that statistical records for each mineral may be carried forward unbroken; this is necessitated by the fact that no "Mineral Resources" volume for 1932 will be issued. Subsequent year books will bear the date of the year of publication in accordance with common practice. It contains 819 pages, divided about equally between descriptive text and charts and tables. The cloth binding is distinctive, and the volume provides the mineral industries with adequate data in more convenient form at an earlier date than elsewhere or heretofore available. Prepared by the United States Bureau of Mines. Copies are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D.C., U.S.A. Price, $1.25.

Designing for Arc Welding.

THIS volume was reviewed in the May, 1933, issue of this journal, but we have been informed by the author, Mr. A. F. Davis, that the price printed in the book is an error. It is obtainable from the Lincoln Electric Co., Cleveland, Ohio, U.S.A., for $1.50, domestic postage prepaid; foreign postage 35 cents. Copies may also be obtained from Buck and Hickman, Ltd., 2, Whitechapel Road, London, E. 1, or from any of their branches.

Mammoth Cunard Castings

Much enthusiasm and interest were shown at the opening meeting of the Lancashire Branch of the Institute of British Foundrymen, when, in addition to the Presidential address, a lecture was given on large steel castings, only brief reference to which can be given here.

WHAT the country owes to castings was the theme of the Presidential address by Mr. Arthur Phillips at the opening meeting of the Lancashire Branch of the Institute of British Foundrymen on October 7, at the Engineers' Club, Manchester. He gave a short historical account of the initial developments in the production of iron castings and their application, citing the "iron bridge" over the Severn, and briefly traced the changes since that time. While other methods and materials had been adopted for structures that were formerly involved castings, gradual developments in all branches of industrial activity had increased the field of usefulness for castings. The greater knowledge of materials has led to the application of exacting specifications, and there is an increasing need for concentration on the production of castings that will meet heavy-duty requirements. It is in this direction, Mr. Phillips said, that foundrymen must strive to progress in order that they may increase the demand for castings. He suggested that the Institute should direct its attention to new uses for castings, and in this way endeavour to increase the demand both at home and abroad. Prizes are already given to those who prepare outstanding papers on various aspects of production, and similar opportunities afforded for the greater application of castings may serve as some encouragement and lead to still wider uses. In all branches of engineering castings play a very important part, and the prominent position this country holds in engineering is largely dependent upon the ability and resourcefulness exercised in the production of castings.

It seemed rather appropriate that this address should precede a lecture on mammoth steel castings, given by Mr. Frank Swift, of Darlington, in which he described, in an interesting and informative manner, the moulding and casting of large Cunard castings, more particularly the stern frame and rudder for the vessel now on the stocks. The set of castings manufactured for this vessel weighed over 540 tons and required approximately 1,000 tons of metal to cast.

It is strange how we are all impressed by the bigness of things, and the large audience present at this lecture was no exception to the general rule. The writer was under the impression that many who listened to Mr. Swift were somewhat discouraged with their own products, which were so puny by comparison with those illustrated in the lecture. It is, of course, true that castings of such bulk involve special problems in manufacture, but size is not always a fair comparison in determining the intricacy of a casting. This is not intended to minimise the stupendous task presented in the production of these large castings, but to direct attention to the large number of complex castings produced with such regularity that their complexities are not always appreciated.

Casting the main piece of the stern frame which required 110 tons of steel. Two open-hearth furnaces were used for the metal, and the photograph, from which this illustration was reproduced, was taken at 3-30 a.m. Note the brilliancy of the vents.

Showing the outer shaft bracket after having been lifted from its mould and stripped ready for annealing. 68 tons of metal was required for the casting. Note the contraction "feathers."

The main principles involved in the preparation of moulds for such large castings are similar to those which characterise the preparation of moulds for other types of castings in other metals and alloys, but the peculiar problems associated with them are intensified because of the higher temperature of the fluid metal, the widely varying thicknesses of metal in the castings, and the unwieldy size of the various parts. This was described in a very practical manner by Mr. Swift, and some indication of the work involved was given in a statement he made about the mould for the main portion of the stern frame. Working three shifts a day, he said, five days were necessary to close the mould for this casting. The majority of cores were made in the mould in the form of drawbacks, and, after being thoroughly baked, assembling had to proceed without undue delay, but with a view to security. The part mentioned was cast between 3 and 4 o'clock in the morning and the accompanying illustration depicts the actual casting.

An important aspect was emphasised that cost is of secondary importance in manufacturing such castings; nothing is left to chance, and every known precaution taken to ensure soundness. But even when the metal has been cast, apparently successfully, it is not possible to state with assurance that the resultant casting is a good one, and the anxiety regarding it is prolonged because the casting must remain to cool down slowly. Thus, it may remain for about

a fortnight, when it is lifted, rough cleaned, and subsequently annealed, considerably extending the period of waiting before the foundrymen can be relieved of anxiety. It is not until the casting is rough machined that its quality can be defined.

Of the many problems presented in the production of such castings, not the least results from the high temperature of the metal and its relatively high contraction when cooling to a normal temperature. For these castings it was elicited from Mr. Swift, as a result of a question by Mr. West, that Sheffield "compo" was used to face the moulds, and the surfaces were given a graphite wash and slecked; tar-sand, though used for small castings up to about 10 cwt., was not used on these larger moulds. Probably the greater difficulties associated with the production of such castings are concerned with contraction, and this will be appreciated when it is realised that an allowance of $\frac{3}{16}$ in. per foot was made. With steel contraction difficulties are intensified because the metal contracts considerably shortly after solidifying, when it is weak in comparison with the mould. Mr. Swift emphasised the need of "feathers" where varying thicknesses or the junction of parts would create undue strain upon the casting, and stated that it was better to err on the side of excessive numbers of these "feathers," than risk a "draw" which would probably lead to fracture. Mr. Longden raised a number of points relating to contraction, but it was impossible to deal adequately with such an absorbing subject in the short time available.

Annealing such castings, as Mr. Swift stated, is a special problem in itself. The awkward shapes and the wide variance in metal thickness increase the difficulties, particularly as it is necessary to attempt to rectify any alteration in shape produced by contraction. Very slow heating up of the annealing furnace is necessary to enable the heat to soak the very thick sections, and the temperature of the furnace was raised much higher than normally to ensure that all parts were adequately heated. The cooling down was probably more important than the heating of the furnace and had to be done slowly to maintain an even balance between the various parts.

A large number of very excellent slides were shown, which proved to be most informative, and at the conclusion a cinematograph display of the works of the Darlington Forge Co., Ltd., where the castings were made, showed the castings as they were presented to the public when the works were opened for inspection shortly before the castings were dispatched to Glasgow.

PROTECTION OF STEEL PIPE LINES

IN connection with the use of steel pipe lines for water supply it will be of interest to give a concise description of the latest methods now being used for protection against rust and corrosion. These are of the most efficient character, and depend essentially upon the use of bitumen, which has, of course, been utilised for thousands of years by many races for protection against water, in the construction of boats, for example, as well as for buildings.

In treating the outside of a steel pipe the bitumen is first applied to the very hot pipe immediately after the manufacture, when it adheres with great tenacity, forming a resistant film. To provide further protection, in view of the patches of corrosive ground through which long mains very often pass, the pipes may afterwards be wrapped in bitumen-saturated jute cloth, or sheathed to a thickness of about $\frac{1}{4}$ in. with a tough seamless bituminous composition. Both these give protection for many years against fresh or salt water and corrosive soil.

In view of the controversy with regard to the use of the somewhat cheaper cement fabricated pipes, such as the ferro-concrete and cement asbestos varieties, it is as well to remember, also, that steel is totally unaffected by substances found in solution in water that are apt to attack the cheaper cement fabricated pipes. This includes, for example, carbon dioxide, found in almost all natural water, either as the free gas or as soluble and easily decomposable calcium and magnesium bicarbonates, which have no effect on steel, although very bad for cement.

Also, steel pipes, especially for soft water, can be supplied lined inside with bitumen, say, $\frac{1}{4}$ in. thick, forming a hard, uniform layer as smooth as glass, which is impenetrable to water. These bitumen-lined pipes have many advantages in addition to their freedom from corrosion, the smoothness of the lining resulting in greater discharge than can be obtained from coated pipes, while their freedom from nodular incrustations and vegetable growths ensures that the discharge will be maintained at a high value. Another important field, also, for the steel pipe is sewage, but as this is almost always alkaline the steel is not affected.

The satisfactory life of a steel pipe is, of course, well indicated by the hundreds of thousands of miles of steel mains operating in the oil industries for crude oil, high-pressure natural gas, salt water, and fresh water. Some of these pipe lines in the United States are over 1,000 miles in length, and more than 500 miles is a common figure, traversing rivers, streams, and marshy and difficult country in the most extraordinary fashion.

Notable, also, is the Iraq oil pipe line now under construction from the oil fields to the ports of Tripoli and Haifa, on the Mediterranean coast, as well as the network of steel pipes in Germany, hundreds of miles in total length, supplying coke-oven gas to a vast area of country.

Catalogues and Other Publications.

William Wilkinson, Shustoke, Warwickshire, has sent us a very interesting little booklet which gives a brief outline of the development of bi-metal to its present-day applications. Bi-metal consists of two different metals fused or sweated together to form a composite sheet metal. It originated with the manufacture of the compound metals known as Sheffield plate and rolled gold, and the historical account given in this booklet will prove interesting not only to users of thermostatic metals, but also to users of all metals. The manufacture of bi-metals is one of the few remaining crafts that depends upon skill and experience for the production of composite metal that is homogeneous and reliable, and in this instance the process has been carried on by the Wilkinsons from its inception, because a predecessor of the present owner of the works at Shustoke was one of the pioneers. Many of these bi-metals are particularly suitable for scientific purposes, while others are ideal thermostatic metals.

A fascinating glimpse of the way in which modern restaurants equip and organise their kitchens is given in "Large Scale Kitchens" (No. 234 of "A Thousand and One Uses for Gas"). Attractively illustrated, this booklet describes a number of recent installations of gas cooking equipment in well-known restaurants, snack bars, clubs, and cafeterias. It can be obtained post free on application to the British Commercial Gas Association, 28, Grosvenor Gardens, London, S.W. 1.

Obituary.

Barrow has lost one of its captains of industry by the sudden death of Mr. John Davison, director and general manager of Barrow Steel Company, on October 7. A native of Consett, Durham, he became commercial manager of the Lanarkshire Steel Company at Motherwell, and subsequently secretary and general manager of Barrow Steel Company, being stationed at the London office, and, on the retirement of Mr. A. Frank Mason, he was appointed general manager at Barrow, and subsequently elected a director. He was an unassuming man, but very diligent and painstaking in the performance of his important duties, and his wide knowledge of every branch of the iron and steel industry was recognised and appreciated in the industry. We join with his many friends in expressing sympathy for his widow and family.

Recent Developments in Tools and Equipment

A TOOLROOM SLOTTER.

A NEW line of toolroom slotters has recently been produced by the Butler Machine Tool Co., Ltd., of Halifax, which are specially designed and manufactured for the difficult duties necessary in the toolroom. They are particularly accurate in operation, and have been designed to maintain absolute rigidity in order to guarantee a maximum error of ·0005 in. in all movements. The machines are built in two sizes, with a maximum stroke of 8 in. and 12 in. respectively.

Special attention has been paid to the design of the tables in order to secure improved rigidity and maintenance of accuracy. The base, as shown in Fig. 2, is of extra width, providing substantial bearings for the saddle, which moves on a narrow guide in the centre. The square slide has similar bearings on the saddle, and both are fitted with adjustable taper strips for taking up wear.

The circular table is of extra depth, the tee slots being machined from the solid, special care being taken to ensure them being at right angles and parallel to one another. An indexing mechanism is fitted, operated from a handle at the front of the square slide, giving divisions for $\frac{1}{12}$, $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$ of a circle. The circular feed to the table has been retained, but the worm is fitted with a simple withdrawing arrangement for use when indexing through large angles.

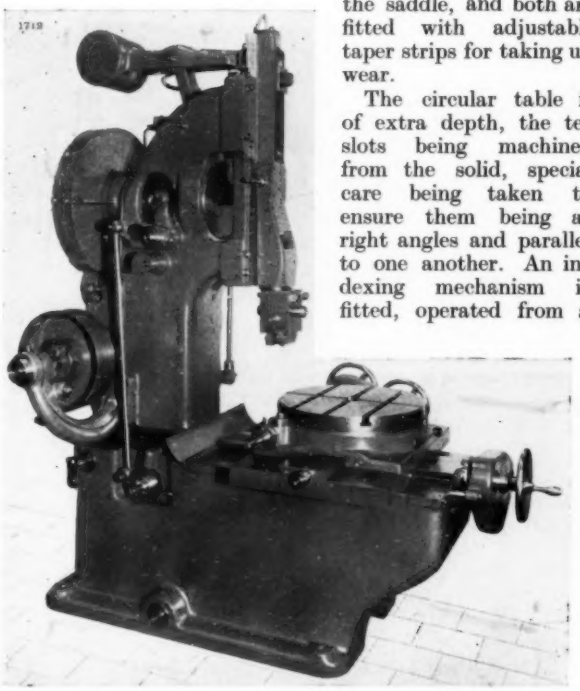


Fig. 2.—Rear view of this precision toolroom slotter.

Both feed screws are fitted with metal covers and ball-thrust bearings at each end. Micrometer collars are fitted to all feed movements, and the periphery of the table is accurately indexed in degrees.

For slotting tapers, the machine is built with the "Butler" patented tilting body, the body being made in two parts, the top portion containing all the driving mechanism, and controls being pivoted on the base. This feature enables the whole body to be tilted to a maximum of 10° either forward or backward, and introduces no weakness into the drive or the tables, as is the case with a tilting ram and tilting table top. Two efficient locking bolts are provided which clamp the two parts firmly together when in the desired position.

To tilt the body, the two securing bolts are first released and the body tilted by means of a worm segment, an index being fitted. To obtain extreme accuracy of setting to gauges a further worm motion can be engaged which enables the operator to effect very fine adjustments; a micrometer collar is fitted, one revolution of which is equal to 2°. The body can be set back to the vertical position by the same mechanism, the final accuracy of setting being obtained from a spirit-level mounted on the body.

The toolbox is of special design, and can be rotated to face front, sides, or back. The whole toolbox is relieved on the return stroke, and tools can be fixed in either the horizontal or the vertical position.

All the driving mechanism is contained in the body, and is similar to that employed for standard high-production slotters, the centralisation of all controls being clearly shown in Fig. 1. The drive is by single belt to a friction-clutch pulley, an efficient brake being incorporated to enable the operator to arrest the ram in any desired position. It is transmitted through heat-treated nickel-chrome steel mitres to a four-speed gearbox, the whole train of gearing running in oil. The range of speeds is 31, 44, 63, and 90 cycles per min., the operating levers being conveniently placed next to the clutch-control lever. All gears are machine-cut in steel, with the exception of the large stroke wheel, which is of special quality cast iron.

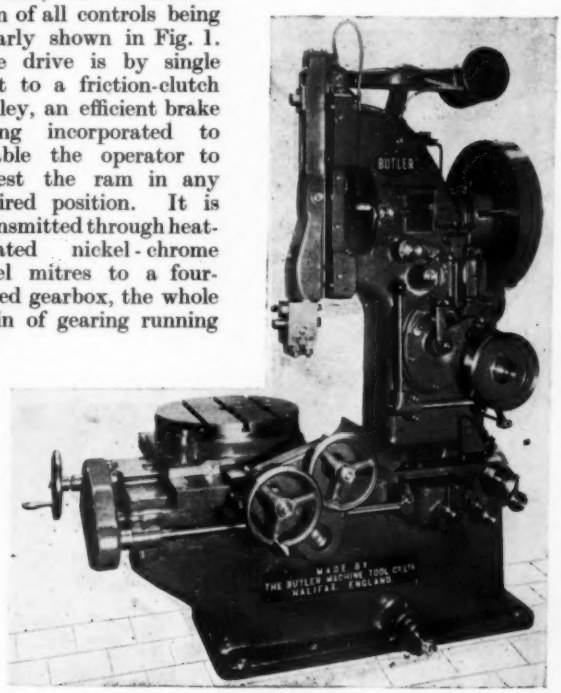


Fig. 1.—Showing centralisation of controls.

The stroke movement is of the "Whitworth" type, giving a uniform quick return of 2 to 1 on all lengths of stroke, and as the cut begins slowly and finishes slowly the life of the cutting tool is greatly increased.

The feed is operated by the "Butler" patented cam feed. This arrangement enables the operator to select any one of seven feeds, ranging from 18 to 125 cuts per inch on the "cross" feed, and from 46 to 320 cuts per inch on the "in" feed, whilst the machine is in motion or at rest. The control lever is placed immediately above the clutch-control lever, as shown in Fig. 1, obviating the necessity of going to the rear of the machine to adjust the throw of a connecting rod. The feed obtained is stopped, started, or reversed from the feed control box at the front, the required

direction of feed being selected by slip gears on the respective screws or shaft.

The "one shot" system of lubrication is used for all bearings in the body, including the stroke mechanism and the ram slides. A self-contained pump is fitted on the working side of the machine, and a single lift of the pump is sufficient to force oil instantly to every point.

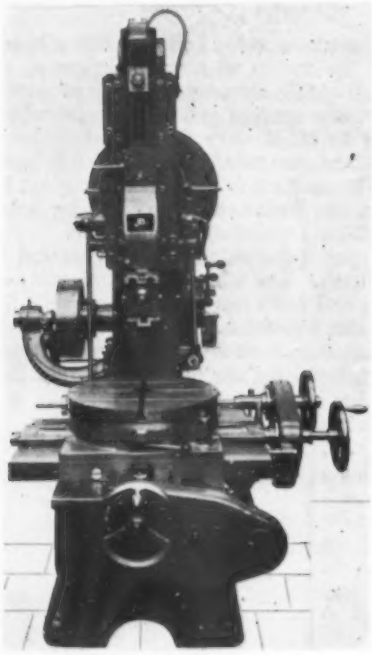


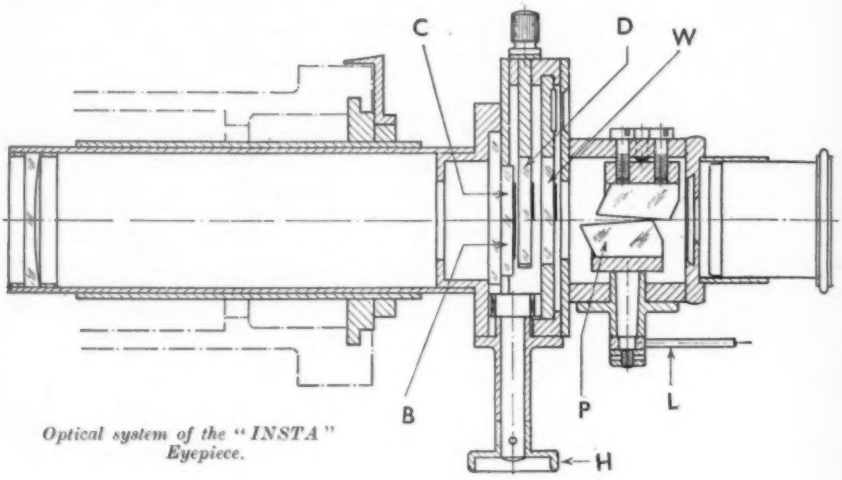
Fig. 3—Showing sturdy construction

The special features of this machine, combined with extreme care in fitting, render it an exceptionally simple machine to operate. The finish is of the highest quality, and all levers, gauges, and parts operated by hand are chromium plated.

Increasing the Quantitative Accuracy of a Spectrometer.

A SIMPLE eyepiece attachment for a spectroscope has been developed and patented by Adam Hilger, Ltd., known as the Insta Eyepiece. It is so designed that a spectrum line of a minor element present in a substance can be accurately compared in intensity with a neighbouring line of a principal element in the substance. The relative intensities of the lines bear a relationship to the proportions of the elements giving rise to them, and when once this relationship has been established for a given substance (a fairly simple matter), quantitative analysis of samples of that substance can be carried out with great rapidity. The most useful application of this eyepiece is in the determination of exceedingly small proportions of elements.

The optical system of the Insta Eyepiece is shown in the accompanying illustration. A movement of the lever *L* rotates the prism *P* in such a way as to move one-half of a chosen spectrum line of the main substance until it is collinear with a neighbouring line of the substance to be estimated. That due to the main substance will usually be brighter than that of the minor element, and when they are thus brought close together their intensity difference is easily appreciated. The brighter one can then be reduced in intensity until it equals the other, by moving a graduated neutral tint filter (neutral tint wedge) *W* by means of a rack and pinion motion actuated by the knob *H*. The amount of reduction in intensity required to equalise the two lines is indicated by a scale. In order to ensure that the reduction shall be uniform throughout the field of view a second fixed graduated neutral tint wedge is placed behind the first at *C*. When the difference in intensity is too great for compensation by the neutral tint wedge alone, the range of the instrument can be increased by interposing a neutral tint filter *D* behind the wedge *W*. The plate *B*



Optical system of the "INSTA" Eyepiece.

is another neutral tint filter placed in the other half of the field to enable it to match the first when the instrument reads zero—*i.e.*, when the wedge system is at its lowest absorption.

In use the manipulation is simple and, for the great majority of measurements, merely consists in moving lever *L* until the chosen lines are collinear and rotating the knob *H* until they are of equal brightness.

A New Gas Volume Recorder.

A NEW gas volume recorder has recently been developed by the Integra Co., Ltd., 183, Broad Street, Birmingham, which operates in conjunction with the usual devices: with diaphram plate or orifice, venturi, or sometimes, in special cases, the pilot tube, the choice depending upon the conditions existing in the main to be controlled.

The essential part of this new instrument is a hollow balanced ring, having a square edge, and resting on knife edges along its axis. The bottom part of this ring is filled with a liquid which merely acts as a seal. At the top of this ring and inside of it there is a gas-tight partition dividing the ring into two chambers separated by the liquid. The two pressures produced by the device inserted in the main are transmitted to the two chambers by means of small flexible connections. These cause the ring to rotate, and take a position of balance governed by a counterweight. The amount of rotation depends upon the pressure difference, and therefore on the rate of flow. A cam fitted to the ring causes a pen-carrying lever to operate through a roller. The shape of this cam is such that the displacements of the pen are proportional to the variations of the flow, and a 7-in. chart is ruled in equal divisions. This important feature facilitates the readings and permits of an easy planimetering of the diagram when required. The recorder is fitted with an indicating metal scale.

Alternatively, an indicator can be supplied possessing a 12-in.-diameter scale which has a very pronounced direct-reading feature. In the indicator the rotation of the ring is transmitted to the pointer by means of a pinion and quadrant arrangement. The indicator type can be supplied as a "blind" transmitter, which electrically operates at distance indicators, recorders, and totalisers; while a multiple-point recorder operated on the same principle can group on one chart the flows of various mains.

New Improved "Alpax" Alloys.

Investigations carried out with a view to increasing the proof stress of "Alpax" have shown that the addition of magnesium and manganese had beneficial effects. An abridgment of a note on the subject by W. H. Grieve and R. B. Deeley published in the Journal of the Institute of Metals is given in this article.

THE discovery of the effect on the mechanical properties of aluminium-silicon alloys of the refinement produced by modification made available for engineering purposes a series of alloys having unique properties compared with the aluminium casting alloys then in common use. Of these the modified 12% silicon alloy, known in this country and France as "Alpax" and in Germany as "Silumin," is probably most well known. The high fluidity, low contraction, and freedom from hot shortness of "Alpax," in conjunction with its high corrosion resistance and the absence, due to its eutectic composition, of the chains of interdendritic shrinkage cavities, which frequently cause leakage, under fluid pressure, of castings of other aluminium alloys, have led to its extensive adoption for engineering purposes. While aluminium castings were formerly used only for parts subjected to negligible stresses, the increasing need for lightness has forced the application of aluminium castings for parts subject to substantial stresses, and there have been cases in which "Alpax" has been considered unsuitable on account of its relatively low-proof stress.

The possibility of increasing the mechanical properties of Silumin has been described by Welter[1] and by G. Sachs.[2] After some preliminary tests it was found that the addition of 0·15–0·30% of magnesium in conjunction with 0·4–0·5% of manganese to Silumin containing 12% silicon, gave an alloy having a higher yield-point than pure Silumin, and also was susceptible to having its properties improved by heat-treatment.

An investigation with a view to increasing the proof stress of Alpax has been carried out by W. H. Grieve and R. B. Deeley,[3] in which the authors found that Sachs' results differed from theirs. A preliminary investigation was commenced on the tensile properties of sand-cast Alpax with additions of magnesium alone up to 5%, in order to determine the general effect of magnesium.

The investigation was carried out in triplicate, one set of test-pieces being tested in the "as-cast" condition, the second set, after tempering in an oil bath for 24 hours at 150° C. (± 1° C.), and the third set after soaking for 4 hours at 510° C. (± 3° C.) in a thermostatically controlled electric furnace, after which they were quenched in water and subsequently tempered for 24 hours at 150° C.

These treatments were arbitrarily chosen as a result of the work of Sachs, and were carried out on the cast bars before machining to the standard B.S.I. test-pieces "C."

The alloys were compounded from commercial ingot containing 12% of silicon, and approximately 0·3% of iron, the total of other metallic impurities being less than 0·1%. In every case the magnesium was added at a temperature of 780° C., following which the alloy was modified, and after a further suitable interval of time was cast.

Determinations were made of tensile strength, elongation, and 0·1% proof stress, and also of the Brinell hardness on all of the bars, the proof stress being determined by loading the test-piece with successive small increments of load, and reading, after the removal of the load, the permanent set produced as indicated by an extensometer. The extensometer readings were plotted in order to determine the stress which had produced a permanent set of 0·1% of the 2 in. gauge length.

1 *J. Inst. Metals.* 1926. 36, 325 *et. seq.*
2 *Z.v.d.I.* 1933. 17, 115-120.
3 *J. Inst. Metals.* August and September, 1933.

The results of the tests show that in all of the conditions addition of magnesium increases the proof stress, by a small amount in the case of the "as-cast" condition, but by large amounts in the case of the tempered and heat-treated conditions.

The addition of magnesium has its most marked effect on the proof stress, which in the "as-cast" condition is gradually increased from about 3·6 tons per sq. in. for pure Alpax to a maximum of 5·6 tons per sq. in. at 2·5% magnesium. The effect of magnesium on the proof stress is even more marked in the case of the heat-treated condition. In the tempered state the proof stress increases rapidly to 8 tons per sq. in., with 0·7% magnesium, after which there is a gradual increase to 9·6 tons per sq. in. with 5% magnesium.

In the fully heat-treated condition the proof stress increases so rapidly that a 1% of magnesium, the permanent set of 0·1% had not been reached when the specimen broke, and it was found by extrapolation of the extensometer readings that the stress required to produce the 0·1% permanent set was higher than the ultimate strength recorded.

The authors carried the investigation further by studying the effect of manganese in conjunction with magnesium in raising the proof stress of "Alpax." For this purpose test-pieces were cast from alloy containing 0·15, 0·3, 0·4, 0·5, and 0·7% magnesium alone. A further series of alloys was also tested, containing in each case the same percentages of magnesium, but with 0·15, 0·30, 0·40, and 0·50% manganese respectively.

The alloys were compounded as in the case of the straight magnesium alloys, but where manganese was added it was added as a 10% hardener, together with the necessary 50% silicon hardener to counteract the aluminium added with the manganese hardener. The manganese hardener was prepared by melting 98% pure manganese and pouring while molten into 99% pure aluminium, stirring thoroughly and ingotting.

Consideration of Results from Mechanical Tests.

Without Heat-treatment.—In the "as-cast" condition the effect of magnesium is progressively to decrease the tensile strength irrespective of the manganese content, but the general effect of manganese is to increase the tensile strength for any particular magnesium content. The optimum percentage of manganese appears to be about 4%. The proof stress is slightly increased by addition of magnesium; manganese has apparently but little effect. The Brinell hardness results in this condition are somewhat variable, and the effect of magnesium is generally rather obscure, although there appears to be a tendency for increased magnesium to increase the Brinell hardness number. Manganese, on the other hand, again shows an optimum at approximately 0·4%. The elongation results show that magnesium steadily reduces the elongation, but for any particular magnesium content, the addition of manganese appears to increase the elongation, the maximum effect being obtained at about 0·3–0·4%.

From the practical point of view, it would appear that for alloy for use in this condition, the magnesium should be as high as is commensurate with a satisfactory tensile strength, whilst the manganese should be approximately 0·4%.

Tempered.—Magnesium within the range tested appears to have but little effect on the tensile strength, whilst manganese increases the tensile strength, and for any particular magnesium content there appears to be a maximum lying between 0·3 and 0·5% manganese.

The proof stress and Brinell hardness are progressively increased by increasing the magnesium, and do not appear to be materially affected by manganese.

The elongation is progressively lowered by increasing magnesium, whilst manganese, again, has an optimum value of between 0·3 and 0·5%. In this condition also the optimum alloy, from a practical point of view, would appear to contain as high a magnesium content as possible, together with approximately 0·4% manganese.

Fully Heat-treated.—The tensile strength is increased by magnesium to a maximum which lies at about 0·5%, after which there is a decrease. Manganese has the general effect of producing maximum values at 0·3% manganese, in the case of alloys containing from 0·3 to 0·5% of magnesium. With other magnesium percentages the effect of manganese is not at all clear.

The proof stress, however, is progressively raised by magnesium irrespective of the manganese content, whilst manganese has no clearly defined effect, except that the peaks in the curves for manganese with magnesium contents of 0·3, 0·4, and 0·5% suggest that a manganese content of 0·3 to 0·4% would be the most suitable for practical purposes. The Brinell hardness curves appear to follow the general behaviour of the proof stress curves, whilst the elongation is affected by both metals in a manner similar to that of the unheat-treated and the tempered conditions.

TABLE I.

Material.	Proof Stress, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.	Elongation, %	Brinell Hardness Number.
Sand-cast.				
"Alpax"—				
(Pure)	3·5–4·0	11–12	6–8	55
Alpha (as cast)	4·3–4·7	10–11	2–4	64
Beta (tempered)	6–8	11–13	2–3	75
Gamma (fully heat-treated)	13–16	16–18	1–2	95
Chill-cast.				
"Alpax"—				
(Pure)	5·5–6·0	13–15	10–12	65
Alpha (as cast)	6·0–6·5	13–15	3–5	70
Beta (tempered)	7·5–9·5	15–17	2–4	85
Gamma (fully heat-treated)	14–17	18–20	1–3	100

In order to obtain any appreciable increase in the properties in the heat-treated condition due to the heat-treatment, the magnesium content must be not less than 0·3%. From the practical point of view, in this condition, the most suitable alloy—that is to say, the one giving the best mechanical properties—would appear to contain 0·5% magnesium with from 0·3 to 0·4% manganese, and this, it will be noted, agrees with the conclusions which were deduced from a consideration of the results in the other conditions.

A number of practical tests has been carried out with alloy of this composition, and a large number of test-pieces has been produced in the foundry, as distinct from the above tests, which were carried out in the laboratory. Based on the results of these foundry-produced bars, conservative average values which may be expected from test-pieces of these new alloys made in general foundry practice are shown in Table I., which also shows the nomenclature which has been adopted in order to avoid subsequent confusion as to the properties associated with the different conditions of heat-treatment.

Castings have been produced which have given, during test periods, very satisfactory service, and during the casting of these it is noted that the freedom of the pure "Alpax" from hot-shortness is entirely unimpaired by the added metals, whilst the fluidity is scarcely affected.

It will be realised from the above that a new engineering alloy has been developed, which has the unique foundry properties of pure "Alpax" in conjunction with considerably enhanced mechanical properties. The relatively inexpensive tempering treatment makes available an alloy having a combination of foundry and mechanical properties not hitherto available in an aluminium alloy. Corrosion tests indicate that the resistance to salt-water corrosion is unaffected.

It may be of interest to note that, following the logical assumption that other metals of the manganese group in the periodic table might have an effect similar to manganese, the authors tested a number of these metals, and from the results obtained the metals, chromium, nickel, cobalt, tungsten, titanium, molybdenum, and vanadium have an effect similar to, and in some cases greater than, that of manganese.

The information given by the authors forms the subject matter described in British Patent Specification No. 394,746.

The Development of Rolls and Rolling Mills.

In his presidential address at the initial meeting of the new session of the Staffordshire Iron and Steel Institute, Mr. Harold E. Cookson, in tracing the history of rolling metals, said it seemed impossible to establish with any degree of accuracy when rolling first originated, but the earliest mention in England, if it could be considered under that heading, was of a slitting mill erected at Dartford in 1590, where, ten years later, the first foundry in England was opened. On the other hand, one authority states that it was at Hyde, in Kinver, that the first slitting and rolling mill was erected, while the manufacture of tinplate was first established at Pontypool by John Hanbury in 1720.

The modern types of mills, as we know them, had their beginning in 1850, and Parkgate is credited with having rolled the first armour plate. All the plates for the steamship *Great Eastern* were made at Parkgate in 1854, and the experience encouraged the firm to become the pioneers in the manufacture of rolled armour plates. Continuing to trace the developments, Mr. Cookson stated that the first Bessemer rail was rolled at Dowlais, Glamorganshire, in 1857, the rails being used on the Midland main line at Derby, while cold rolling of iron was patented in 1859 by Bernard Lauth. The British Admiralty first used steel as an exclusive main material of construction in 1876, the plates being ordered from the Landore Steel Co., and it was also about this year that the steel rail substituted the iron rail.

Mr. Cookson had much to say about roll founding, and, while it was obvious Staffordshire was not the birthplace of the roll-making industry, he said it certainly could claim to have been the home of the roll trade. Mr. S. Huxley, a well-known figure in the South Wales trade, had told him that his father rolled the first steel sheet in Great Britain in 1876. The steel bloom was made at Panteg Steel Works, and was brought to Thompson and Hatton's Bradley Tinplate Works at Bilston, where both Mr. Huxley and his father were working. Two or three days after its arrival it was surreptitiously put in the ball furnace with other iron, heated up and then rolled. Those who were told the steel was going to be rolled apparently expected the experiment would be unsuccessful, but Mr. Huxley told him it rolled beautifully, and everybody was delighted. It was of particular interest to note that the chilled rolls used in this instance were made by Charles Akrill, of West Bromwich, the originator of the company with which Mr. Cookson is so intimately associated. He believed Mr. Huxley was the only man living of those who were present on this historic occasion.

Business Notes and News

Copper Development Association.

The Copper Development Association has been incorporated as a company, with offices at Thames House, Millbank, S.W. 1. The Rt. Hon. Sir Auckland Geddes, G.C.M.G., K.C.B., Mr. A. Chester Beatty, and Sir Harry D. McGowan, K.B.E., are Honorary Presidents of the new Association, which will be directed by a council, of which Mr. D. Owen Evans, M.P., is chairman, and Lieut.-Col. Hon. R. M. P. Preston, D.S.O., is vice-chairman. The conduct of detailed business will be vested in a Management Committee, of which Mr. A. D. Storke will be chairman, and on which most of the important copper interests, including the trade associations, will be represented. Mr. S. S. Taylor, C.M.G., D.S.O., will be vice-chairman of the Management Committee, and the other members will be Mr. W. R. Barclay, Mr. Thomas Bolton, Mr. J. C. Budd, Mr. G. W. Mullins, Mr. E. Pam, Mr. C. H. Schneider, and Mr. A. J. G. Smout.

Mr. D. P. C. Neave, who has been appointed General Manager and Secretary, has already visited many of the important users of copper, and will shortly submit to the Management Committee recommendations as to further staff required and the general lines of work to be undertaken.

Contact has been established with the American Copper and Brass Research Association, and with the Copper Institute of Germany, with a view to the interchange of information. It is proposed for the present to concentrate on development of the extended uses of copper rather than research work, as it is felt that this is far behind research. Preliminary investigation indicates that the Association has in front of it a useful field, and should be able to assist not only producers but fabricators of copper in enlarging their operations.

New Soviet Steel Plant.

Following the Magnitogorsk and Kuznetsk giant metallurgical plants, the third great metallurgical works of the Soviet Union—Azovstal, in Mariupol,—has been put into operation. The first blast-furnace has already been blown. The first section of this giant plant is to consist of four powerful blast-furnaces of 930 cbm. each, 31 tipping Marten furnaces, each of 250 cbm., a blooming mill, a steel rail mill, a coke chemical combine of a capacity of 1,300,000 tons of coke per annum, and the Kamysh-Barun ore fields and concentration plants. The first section of Azovstal is designed for an output of 924,000 tons of pig iron, 1,315,000 tons of steel, 660,000 tons of rails, and 180,000 tons of bloomed metal. The building of this plant is claimed to have solved the problem of the utilisation of the rich local Kerch ores, containing vanadium, essential for the manufacture of super-quality steel.

International Competition for Aluminium Furniture.

The International Congress of Modern Architecture has decided to offer to competitors in the Furniture Competition, which is being organised by the International Bureau for Aluminium, a special prize of 1,000 Swiss Francs. The Congress is doing this in order to express in a practical way the interest it takes in the use of aluminium for decorative purposes. This prize will be awarded independently by a jury chosen from architects who are closely connected with this Congress. In response to a large number of requests it has been agreed to postpone the closing date of the Furniture Competition, fixed by Article IX. of the rules, until November 1. This should enable competitors to complete their designs or models more easily, and the announcements regarding the awarding of the prizes will now be made not later than December 15.

Institute of Metals Programme for 1933-34.

The Institute of Metals has just issued the programme of its activities for the session 1933-34. There will be three general meetings of the Institute—on March 7–8 and in September,—at each of which a number of important original metallurgical communications will be presented for discussion, whilst on May 9 the twenty-fourth annual May lecture will be delivered. In addition to the meetings of the parent organisation, there will be held monthly throughout the coming session meetings of the Institute's six local sections, which are located, respectively, in Birmingham, Glasgow, London, Newcastle-on-Tyne, Sheffield, and Swansea. Before these sections there will be read more than 40 papers, whilst, in addition, there will be exhibitions of cinematograph films of metallurgical interest. The programmes of each section are designed to appeal particularly to persons engaged in local industries. Thus, at Birmingham, papers will be read on "Nickel and Nickel Alloys," "Age Hardening Copper Alloys," and "Rolling Mill Practice," whilst, in addition, there will be a symposium on defects in cold working.

New Manvers Main Coking Ovens.

Last year the board of the Manvers Main Colleries, at Wath-upon-Dearne, near Barnsley, decided to scrap the old coke-oven plant and erect a modern installation on the same site. The battery of 30 ovens is now completed, and was lighted up recently, when a special function was held. When the full battery is completed there will be 45 ovens, and they will deal with over 1,000 tons of slack per day.

This by-product coke-oven plant, the contract for which was placed with Simon-Carves, Ltd., Cheadle Heath, Manchester, is claimed to be the most modern of its kind in the world. The ovens are of the "underjet" twin-flue type, with coal and coke-handling equipment, coke-screening plant, and by-product plant, which includes gas condensers, an electrical de-tarrer, three ammonia and three benzole scrubbers, and a complete crude and rectified benzole plant eliminating primary distillation and capable of producing 10,000 gals. of motor spirit from two stills. A special feature of the ovens is the Wolff patent self-sealing doors, which entirely supersede the method of clay-luting, and prevents the waste of heat and gas. A striking external feature of the installation is the reinforced concrete tower, 140 ft. high, for the coal service bunker. An important by-product will be 3,000,000 to 4,000,000 cub. ft. a day of surplus gas, which a boosting plant will supply to customers like local authorities for town lighting and heating supplies, steelworks, glassworks, brickworks, and other local industries.

Plans for a Forth Bridge Road.

The Ministry of Transport has informed the Kincardine Joint Bridge Committee at Stirling that it will make a grant of 75 per cent. towards the construction of a road bridge over the Firth of Forth, but not before the end of the financial year next March, while the grant for the following year will be limited to £120,000. In view of this support the Committee decided to recommend the contributing authorities to go ahead, and to approach the burghs of Falkirk and Dunfermline for increased contributions.

The tender for the foundation and steelworks, amounting to £238,609, by the Cleveland Bridge and Engineering Co., Ltd., Darlington, was provisionally accepted. The estimated cost of the bridge, including approach roads, acquisition of land, and engineering fees, is £390,000.

The length of the proposed bridge is half a mile between Kincardine and Higgins Neuk. It will have twelve 50-ft. spans, with two central spans of 150 ft. each, which can be pivoted for the passage of ships. The bridge will reduce the distance between Fife and Glasgow by 12 miles, and Edinburgh by 20 miles, and, providing more direct route, will relieve traffic congestion at Stirling.

Stainless Steel Aeroplanes.

Considerable development is being made in the application of stainless steels to aeroplane construction, and it is expected that a large number of stainless steel aeroplanes will be delivered to the Fleet Air Arm before the end of the year. These are being built by the Hawker Company, following experiments made with single aeroplanes built of this material. It has been demonstrated that the normal type of aeroplane, which is fully resistant to corrosive influences on land, deteriorates rapidly in marine conditions of service. The new machines will consist almost entirely of stainless steel, the only items in the air frames not of this material will be the fuselage and wing coverings, and certain bearings which will continue to be made from phosphor bronze. The stainless steel components include such details as nuts, bolts, and split pins; even the streamline wires have, after some difficulty, been made in the same material.

The difference in weight, compared with the standard product, is very little, and amounts to an addition of only about 2%. The cost of these aeroplanes is naturally much higher, but it is assumed that this will be more than counterbalanced by their long life and by savings on replacements.

New Blast-Furnace to Start.

It is announced that Messrs. Dorman, Long and Co. expect to start a new blast-furnace at their Cleveland Steelworks, South Bank, at the end of this month. The furnace is claimed to be the most modern on the North-East Coast, and is designed for an output of 2,800 tons of iron per week. It has been planned for the production of basic iron for the steelworks, using as large a proportion of Cleveland iron stone as possible. The new furnace replaces an old one of half the capacity, and is the first step in plans for completely modernising the company's blast-furnace plant.

Since the beginning of the year four additional blast-furnaces have been lighted, and the one referred to above will be the fifth, bringing the number in operation on the North-East Coast up to 20.

Transfer of Old-established Iron Pipe Works.

Cockrane and Co., Ltd., which was taken over by the Cargo Fleet Iron Co., Ltd., some years ago, has been formed into a new Company—Cockranes (Middlesbrough), Ltd. There were rumours some time ago that the Cargo Fleet Iron Co. had disposed of these works to the Stanton Ironworks. The formation of a new Company marks the definite transfer of this old-established iron-pipe manufacturing firm to the Stanton Ironworks Co., Ltd., and while it is not possible to state in what direction developments will be effected it is confidently stated that the works will be continued at Middlesbrough and developed. There are three blast-furnaces at these works, but it is very unlikely that any will be restarted, at least for the present, since the Stanton Company are large manufacturers of pig iron, and will, no doubt, supply all the immediate needs of the Middlesbrough works.

New Steel Mills.

The Whitehead, Thomas Bar and Strip Co., Ltd., has been registered as a private company, with a capital of £100,000 in £1 shares. Of the capital, 50,000 "A" shares are issuable to the Whitehead Iron and Steel Co., Ltd., which are to be held by this company in the first place, and 50,000 "B" shares, issuable to Richard Thomas and Co., Ltd., to be held by this company in the first instance.

The new company has been formed to acquire land at the Redburn Works, Scunthorpe, Lincs., to establish and operate there finishing mills in all descriptions of steel products, especially bars and strip, and to carry on the business of manufacturers and merchants of iron and steel in all its aspects.

The directors are: Mr. Lionel D. Whitehead (first deputy chairman and managing director), Mr. Gustavus H. Lathan, and Mr. Arthur G. Brown, appointed on behalf of the holders of the "A" shares, and Sir William J. Frith (first chairman), Mr. Albert W. Kieft, and Mr. Chas. Phillips, appointed on behalf of the holders of class "B" shares.

Developments of the Mechanite Institute.

We are informed that the International Mechanite Metal Co., Ltd., of 14-20, Church Street, London, N. 1, has now been completely organised and Mr. E. M. Currie, late of Messrs. Alfred Herbert's, Ltd., of Coventry, has been engaged as technical manager. Mr. Reece, chief assistant to Mr. Smalley, of the Mechanite Corporation of the United States of America, will be with the Company for some months to assist licensees. Messrs. Ashmore Benson, Pease and Co., Ltd., of Stockton-on-Tees, is the first important licensee of this company.

The extensive development of Mechanite in the United States of America has been based on the establishment of 14 grades of Mechanite, each having separate and distinctive properties, and claimed to meet every need of engineering requirements, including resistance to acids, abrasion, erosion, heat, and possessing exceptional strength and toughness. Each grade is controlled to meet specific service requirements. The company establishes the manufacture of each of these in the foundry of the firm to which it grants a licence. Complete metallurgical and foundry service is rendered.

Exchange of information between the Mechanite Metal Corporation of America and the company has been arranged, and the licensed foundries in Great Britain will receive the information which is issued from time to time to the American licensees by the Mechanite Institute, of which Mr. Smalley is president.

North-East Coast Institution of Engineers and Shipbuilders.

At a recent meeting of the Council of the above Institution it was decided to award the Institution Scholarship, valued at £100 per annum, to William Leslie Stewart, and a grant of £50 to John Campbell Matthew. Both are students at Sunderland Technical College, and prior to entering that College were apprentices in the employment of Messrs. Richardsons, Westgarth and Co., Ltd., Sunderland.

The George Mitchell Harroway Scholarship, valued at £100 per annum, has been awarded to Guy Gowland Harforth, who is an apprentice in the employment of the Furness Shipbuilding Co., Ltd., Haverton Hill-on-Tees. He will study at Armstrong College, Newcastle-on-Tyne, for the degree of B.Sc. in naval architecture.

In addition to the above awards, the scholarships of Messrs. E. J. C. Statham (1931 scholar) and J. C. Brown (1932 scholar) have been continued for another year. The total value of the grants awarded by this Institution is £450.

Restarting Idle Plant on Tees-side.

A steady expansion of industrial activity on Tees-side necessitates the restarting of more idle plant. Messrs. Dorman, Long and Co., Ltd., are preparing coke-ovens at Redcar Ironworks for the resumption of operations, and are shortly to reopen the Challoner Ironstone Mine, while work may soon be resumed at their Acklam Steelworks.

September imports of iron and steel to the Tees from foreign ports and coastwise totalled 2,377 tons, compared with only 989 tons in the previous month. September exports of iron and steel from the Tees were some 4,000 tons lower, compared with August, due to a decline in exports of finished iron. The total shipments amounted to 35,987 tons, against 39,682 tons in August.

Magnetic Chart of the Ukraine.

A magnetic chart of the whole of the Ukrainian Soviet Republic will soon be available, the scientists of the Odessa Geophysical Observatory, under the leadership of Professor M. A. Aganin, having completed the photographic work in the Ukraine which forms the basis of the chart. The magnetic photographs have established the fact that the so-called Kursk Magnetic Anomaly extends over territory far beyond Kursk, reaching Kharkov. By analogy this would suggest that in the western region of the Odessa province large deposits of ore may be found.

Sheffield Producing more Steel.

Since the beginning of this year, said Mr. C. J. Walsh, in his speech after being installed as Master Cutler, there has been a gradual but definite improvement in the steel trade of this country. The average monthly output of steel over the first eight months of this year is more than 99,000 tons a month greater than the monthly average for the whole of 1932, and with the addition of several large furnaces that have recently been started in various parts of the country, this output will be substantially increased.

Report on Metric Units of Volume.

The Chemical Divisional Council of the British Standards Institution has decided that in all British Standard Specifications prepared for use in the chemical industry, in which reference to metric units of volume is made, the unit to be employed shall be the millilitre (abbreviation ml.) in preference to cubic centimetres. For example, the millilitre has been adopted as the unit in terms of which British Standard volumetric glassware shall be calibrated, and as the unit to be employed in the description of analytical methods. The decision to adopt this unit was taken after careful consideration involving a detailed study of the history of the metric units of volume, and of current practice.

A similar recommendation was made by the Joint Committee for the Standardisation of Scientific Glassware in 1924, and has since been adopted in many important publications. Some journals, however, still retain the use of "c.c.". The British Standards Institution consider that the general use of the millilitre in all journals is highly desirable.

The relevant facts are outlined in a report which has just been issued by the British Standards Institution, copies of which can be obtained from their Publications Department, 28 Victoria St., London, S.W. 1, price 2s. 2d. post free.

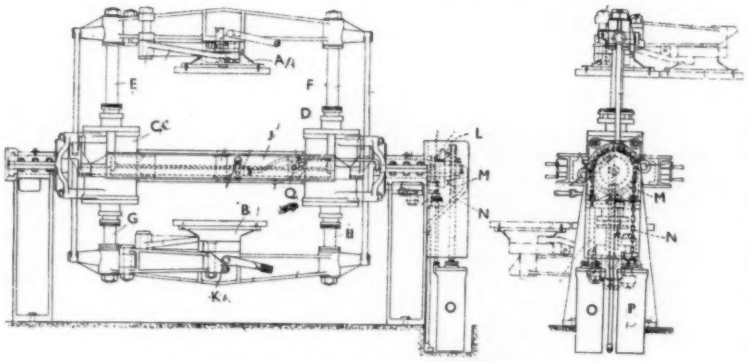
Some Recent Inventions.

The date given at the end of an abridgment is the date of the acceptance of the complete Specification. Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton Buildings, London, W.C. 2, at 1/- each.

Moulding Machines.

MANY developments in the design of moulding machines have been concerned primarily with a reduction in the cost of preparing moulds and this has been achieved by reducing the labour involved and in positioning and withdrawing the patterns and moulding boxes. A recent development of this character concerns a turnover moulding machine, having a pair of rams A and B which are moved in unison by two pistons in cylinders C and D and rods E, F, G, and H, in the accompanying illustration, to press sand in a box on one side of the table J, while drawing a mould at the other. The rams are carried by parallel arms so that they can be swung away from the beams which carry them, and the beams are constrained to remain parallel with the table by links, levers, and shafts. Each ram is held in operative position by a catch K which is actuated by a handle or pedal.

The table is carried by trunnions, the latter having a ring feathered thereon so that it can be moved axially by a handle to bring a projection into a recess of the frame to lock the table J or another projection L into a recess of a sprocket M, which can be rotated through 180° alternately in opposite directions by a chain N and fluid-pressure cylinders O, P. The table is thus inverted by always turning in the same direction, the sprocket being returned idly. A vibrator may also be started by a valve Q.



Recently developed turnover moulding machine.

In a modification each beam may be made to swing about one piston rod, the rams being axially adjustable by screws. The turnover mechanism may rotate the table in opposite directions after successive moulding operations, and, for small machines, worm gear or a simple hand-wheel may be employed. A single cylinder may also be used in place of the two cylinders C and D.

388,888. L. H. HINES, Heaton Chapel, Stockport, Cheshire. March 9, 1933.

A Process of Producing Chromium.

A PROCESS of producing chromium has been devised on a commercial scale by the reduction of chromium oxide with the aid of circulating hydrogen, which is claimed to overcome many difficulties. The chromium oxide is reduced at a temperature above 1,600° C. in a reaction chamber, the source of heat being disposed within the outer walls of the chamber, the outer casing being maintained at a relatively low temperature by means of a heat-insulating liner between the casing and the source of heat.

At the high temperature employed, hydrogen, with water-vapour content, has a reducing action on the chromium oxide. It has been found, however, that temperatures of —60° C. to —70° C. are sufficient for the removal of water vapour from the circulating hydrogen, which can readily be obtained by the vaporisation of mixtures of liquid carbon dioxide and acetone, ether, trichlorethylene, or the like, or by the vaporisation of ammonia under reduced pressure. The cost of removing moisture from the hydrogen by these means is much less than with liquid air; the process is, therefore, commercially practicable, particularly as the source of heat is arranged within the receptacle, since there are no limits to the size of the reaction vessel and, consequently, to the production capacity of the apparatus.

It is preferable to employ a heating element of molybdenum, or equivalent material, such as tungsten, as the source of heat, since this permits of the use of temperatures above 2,000° C. Since molybdenum, tungsten, and the like are less readily oxidised by hydrogen containing traces of oxygen and steam than chromium, the heating element of molybdenum, or equivalent material, may be so disposed within the reaction chamber that it comes into contact with the hydrogen atmosphere, because a hydrogen atmosphere, which contains so small a quantity of steam and oxygen that it is suitable for the reduction of chromic oxide, is absolutely without effect upon such metals as molybdenum and tungsten. Thus, for example, the heating element of molybdenum or tungsten, in the form of a ribbon or wire, may be wound spirally on the outer surface of an inner tube of refractive material. Such inner tubes being rarely absolutely gas-tight, the hydrogen atmosphere usually permeates through and comes into contact with the heating element.

The necessary temperature can be still more advantageously attained, it is claimed, by the inductive heating of metallic chromium. A certain quantity of chromium is melted initially, for instance, at the bottom of the reaction chamber, and the chromium oxide is placed upon this chromium. The liquid chromium will then serve as a source of heat for the process, and the quantities of chromium metal reduced by the process will mix with the already liquid chromium metal. In this case, the energy necessary for heating the chromium bath which serves as a source of heat in the interior of the vessel may be supplied by means of an induction coil disposed outside the container.

389,963. HERAEUS-VACUUMSCHMELZE AKTIENGESELLSCHAFT, of Hanau a Main, Germany, and Dr. WILHELM ROHN, also of Hanau, Germany. March 30 1933.

Ball Mills.

METAL bronzes are made in paste form comprising flaked metal possessed of and retaining the leafing or mirroring quality, suspended in a liquid which is compatible with the usual varnish vehicles, or is a paint or varnish thinner, and is free from ingredients which impair the leafing quality; suitable liquids are varnolene, turpentine, benzol, and paint-maker's naphtha. The leafing operation may be effected without polishing or ageing by treating clear flaked metal powder with a solution of a leafing agent, such as stearic, palmitic or oleic acid, alpha naphthylamine, and palm oil or olive oil, in a liquid as defined above; an emulsifying agent, such as aluminium stearate, and trieth.-anolamine stearate, may be included. In the case of aluminium, for example, the flaked metal powder may be simply agitated in such a solution at a temperature of about 50° C., in the presence of air, and subsequently excess liquid is removed according as dry powder or paste is required; or the flaking and leafing operations may be effected simultaneously in an impact grinding device such as a ball mill, in the presence of the solution of the leafing agent, and in the presence of air or oxygen. Other metals, such as copper, zinc, and tin, or their alloys, may be used.

391,839. METALS DISINTEGRATING CO., INC., New Jersey, U.S.A.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£100	0	0

ANTIMONY.

English	£37 10 0 to £40	0	0
Chinese	26	10	0
Crude	—		

BRASS.

Solid Drawn Tubes	lb.	9½d.
Brazed Tubes	„	11½d.
Rods Drawn	„	8½d.
Wire	„	7½d.
*Extruded Brass Bars	„	4½d.

COPPER.

Standard Cash	£35	15	0
Electrolytic	39	0	0
Best Selected	37	15	0
Tough	37	5	0
Sheets	66	0	0
Wire Bars	39	5	0
Ingot Bars	39	5	0
Solid Drawn Tubes	lb.	10½d.	
Brazed Tubes	„	10½d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	2	7
‡Ferro Tungsten	„	0	2	4
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/– per unit	ton	29	0	0
NOMINAL: 4–6% Carbon, scale 7/– per unit	„	21	5	0
NOMINAL: 6–8% Carbon, scale 7/– per unit	„	19	15	0
NOMINAL: 8–10% Carbon, scale 7/– per unit	„	18	17	6
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	„	30	15	0
Guar. max. 1% Carbon, scale 12/6 per unit	„	33	10	0
§Guar. max. 0·7% Carbon, scale 15/– per unit	„	37	2	6
‡Manganese Metal 97–98% Mn.	lb.	0	1	4
‡Metallic Chromium	„	0	2	8
§ Ferro-Vanadium 25–50%	„	0	12	8
§ Spiegel, 18–20%	ton	7	10	0
Ferro Silicon— Basis 10%, scale 3/– per unit	ton	5	2	6
20/30% basis 25%, scale 3/6 per unit	„	7	17	6
45/50% basis 45%, scale 5/– per unit	„	11	17	6
70/80% basis 75%, scale 7/– per unit	„	18	10	0
90/95% basis 90%, scale 10/– per unit	„	30	0	0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	13	15	0
§ Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20–25%	ton	15	18	0
§ Ferro-Molybdenum, Molyte	lb.	0	5	6
§ Calcium Molybdate	„	0	5	9

FUELS.

Foundry Coke—			
S. Wales	£1 0 0 to	1	5	0
Scotland	—	1	8	0
Durham	1 1 0 to	1	5	0
Furnace Coke—				
Scotland	—	1	5	6
S. Wales	—	0	15	0
Durham	—	0	14	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£53	0	0
*Commercial Ingots	43	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	9
*Cored Bars	„	0	0	11

LEAD.

Soft Foreign	£11	17	6
English	13	5	0

MANUFACTURED IRON.

Scotland—			
Crown Bars, Best	£10	5	0
N.E. Coast—			
Rivets	10	15	0
Best Bars	10	5	0
Common Bars	9	5	0
Lancashire—			
Crown Bars	9	0	0
Hoops £10 10 0 to	12	0	0
Midlands—			
Crown Bars £8 0 0 to	9	0	0
Marked Bars	12	0	0
Unmarked Bars	—		
Nut and Bolt Bars £6 15 0 to	7	10	0
Gas Strip	10	12	6
S. Yorks —			
Best Bars	10	15	0
Hoops £10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	8d.
*Cored Bars	„	10d.
†Strip	„	10½d.
†Sheet to 10 W.G.	„	11d.
†Wire	„	1/–
†Rods	„	11d.
†Tubes	„	1/4
†Castings	„	1/1½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	6	0
Foundry No. 1	3	7	6
„ No. 3	3	5	0
N.E. Coast—			
Hematite No. 1	2	19	6
Foundry No. 1	3	5	0
„ No. 3	3	2	6
„ No. 4	3	1	6
Silicon Iron	3	5	0
Forge	3	1	6
Midlands—			
N. Staffs Forge No. 4	3	1	0
„ Foundry No. 3	3	6	0
Northants—			
Foundry No. 1	3	5	6
Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	2	19	0
„ Foundry No. 1	3	6	0
„ Foundry No. 3	3	3	6
West Coast Hematite	3	6	0
East „ „ No. 1	3	0	0

SWEDISH CHARCOAL IRON AND STEEL.

Kr. per English ton @ 18–16 to £1 approximately.

Pig Iron Kr. 90
Billets Kr. 230-290 £12 13 4–£16 0 0
Wire Rods Kr. 265-320 £14 12 6–£17 12 6
Rolled Bars (dead soft) Kr. 185-210 £10 4 0–£11 11 0
Rolled Charcoal Iron Bars Kr. 290 16 0 0
All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£30	0	0
„ Braziery	27	0	0
„ Wire	—		
Brass	20	0	0
Gun Metal	26	0	0
Zinc	11	0	0
Aluminium Cuttings	73	0	0
Lead	11	0	0
Heavy Steel—			
S. Wales	2	10	0
Scotland	2	7	0
Cleveland	2	6	0
Cast Iron—			
Midlands	2	0	0
S. Wales	2	6	6
Cleveland	2	6	0
Steel Turnings—			
Cleveland	1	11	6
Midlands	1	7	0
Cast Iron Borings—			
Cleveland	1	2	0
Scotland	1	15	0

SPELTER.

G.O.B. Official	—		
Hard	£13	15	0
English	17	2	0
India	15	15	0
Re-melted	16	0	0

STEEL.

Ship, Bridge, and Tank Plates Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	9	0	0
„ „ (Marine) „	—		
„ „ (Land), N.E. Coast	10	0	0
„ „ (Marine) „	10	10	0
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails £8 10 0 to	8	15	0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic £8 2 6 and	8	12	6
Medium Basic £6 12 6 and	7	2	6
Soft Basic	6	0	0
Hoops £9 10 0 to	9	15	0
Manchester Hoops £9 0 0 to	10	0	0
Scotland, Sheets 24 B.G.	10	5	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/–
Finished Bars 18% Tungsten	„	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	„	3d.
Under ¼ in. to ⅛ in.	„	1/–
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅜ in.	„	3d.
„ „ ½ in. × ¼ in.	„	1/–

TIN.

Standard Cash	£224	0	0
English	224	10	0
Australian	—		
Eastern	229	0	0
Tin Plates I.C. 20 × 14 box	0	17	0

ZINC.

English Sheets	£26	0	0
Rods	30	10	0
Battery Plates	—		
Boiler Plates	—		

* McKechnie Brothers, Ltd., quoted Oct. 12. † C. Clifford & Son, Ltd., quoted Oct. 12. ‡ Murex Limited, quoted Oct. 12.

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices quoted Oct. 12, ex warehouse.